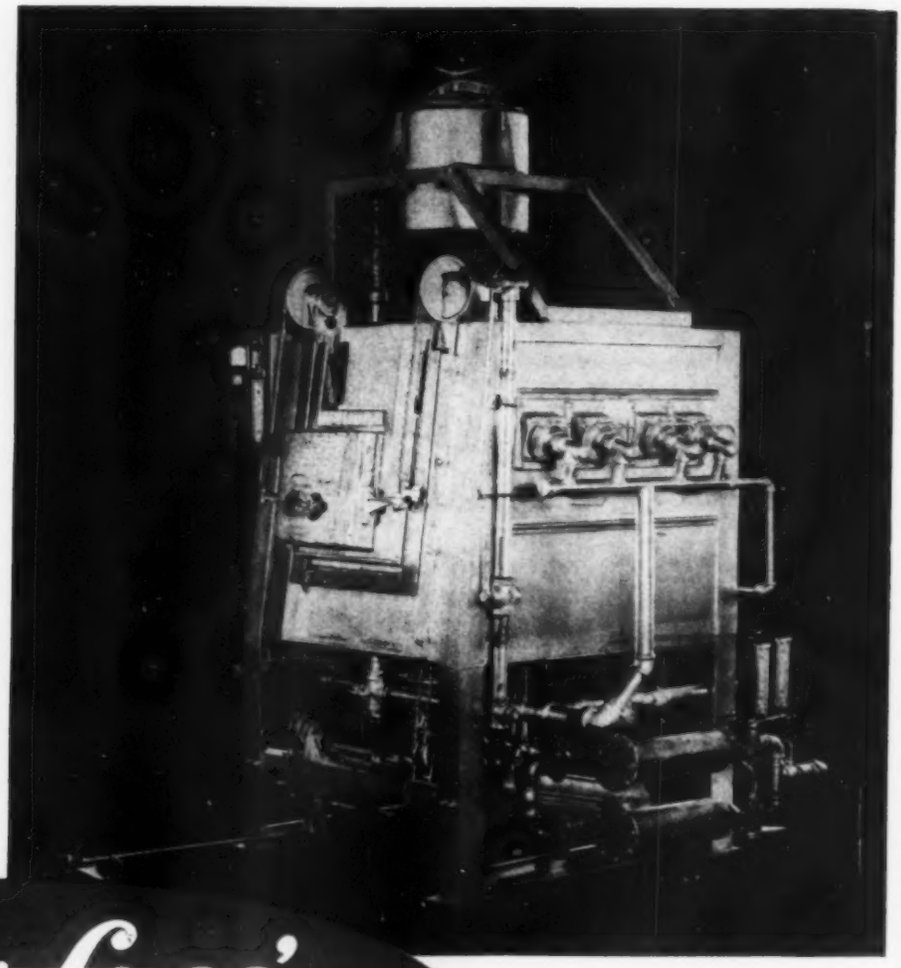
METAL

FEBRUARY 1947

PROGRESS



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ERNEST E. THUM, Editor

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RYERSON STEEL

Sheet and strip, rolled on continuous mills, require a lower phosphorus content than when thin gages are pack rolled. This encouraged the development of a practice for dephosphorizing bessemer steel, by blowing it hot, holding back the slag in the vessel by a temporary wood-block dam, and adding the ingredients of a dephosphorizing slag to the stream of metal as it is poured into the ladle. Such a steel has different qualities from an open-hearth steel of the same nominal analysis, and this fits it for certain large applications — flat rolled products, rods and wire.

DEPHOSPHORIZED BESSEMER STEEL

By G. M. YOCOM

Metallurgical Assistant to General Manager, Wheeling Steel Corp., Wheeling, W. Va.

ADVENT of the hot and cold continuous strip mills wide enough for processing sheets and tin plate presented a formidable problem to the bessemer departments. Plants solely engaged in making bessemer steel and equipped with mills confined largely to the rolling of sheet and tin bar were forced to seek other outlets for their production, or change the properties of the steel to meet the demands. As a matter of fact, openhearth steel largely supplanted bessemer in the grades supplied to cold reducing mills.

Hot Pack Rolled Sheets — In the old-style hand sheet mills, employing the hot pack rolled method, phosphorus plays a prominent part in differentiating the grades of steel used. When pack rolling the lighter gages (22 gage, or 0.030 in., and lighter, where packs are doubled) the pressure of the rolls tends to weld the sheets together. This effect can be counteracted by adding phosphorus to the steel. Specifications for ordinary sheet and tin bar call for up to 0.110% P in openhearth steel and bessemer is furnished in the range of 0.090 to 0.110% P. In special orders where very light gage is involved or stiffness and high strength is a requisite of the final product, phosphorus is added to bessemer steel to as much as 0.125%. However these higher additions often hinder deep drawing, and phosphorus is therefore usually held to a minimum consistent with satisfactory pack opening when rolling the various gages. The higher phosphorus contents do not present a difficult problem as to segregation, largely because the ingots used for sheet bar are generally of small cross section and the sheets are cross-rolled. The sheet does not age nor does embrittlement develop to a great degree after hot dip coating with zinc or tin; probably this is partly due to the method of finishing, which produces a sheet in more stable equilibrium than the cold reduced plate.

Cold Reduced Sheets — The entrance of tandem mills presented a different picture with respect to the phosphorus content and its relation to cold reduction. Steel quality and chemistry are of more importance to the production of a successful deep drawing sheet in tandem mills than in the hot pack rolled process.

Aging characteristics became a problem, partly due to chemistry and also to a change in physical conditions. After final temper rolling, cold reduced sheets are probably in a state of relatively unstable equilibrium which increases the sensitivity of the steel to certain variables.

Segregation of the elements had to be given more attention, especially in the rimmed steel grades, due to the large slab ingots required for wide sheets rolled in one direction. Phosphorus, with its high propensity for segregation, then became a problem, especially in the higher phosphorus grades. A reduction in the segregation, and also the phosphorus, was necessary to provide uniform cold rolling performance, uniform drawing properties and a high standard of flatness in the finished product.

Of no little importance was the fact that the difference between success and failure began to be measured by the trade by the loss of two or three stampings out of a hundred!

All in all, the conditions of processing and

the properties of the final product generally demanded lower and narrower ranges of the usual elements, and also limited the nitrogen and oxygen contents. Phosphorus well under 0.050% became the standard; such a steel minimized work hardening and its strong unfavorable effect in deep drawing work. (However, phosphorus is added to 0.150% in openhearth grades for ordinary forming work where high strength and stiffness are required in the finished product.) The element serves no useful purpose in cold reduction or final drawing quality and is currently held as low as possible in most grades.

Confining this discussion to bessemer steel of 0.100% P, it developed that the rimmed steel grades were successfully cold reduced to gages of about 0.015 in. during the early period of relatively low rolling speeds. As mill speeds were gradually increased from 400 ft. per min. to 1800 and higher, the lighter gages became difficult to produce on some mills and impossible on others without undue breakage, less in yield, and low production rates. There remained, however, a large field of application for bessemer steel in light gages for products in the class of consumers' goods where only a good forming quality is involved; regular bessemer, low in carbon and manganese and with 0.100% phosphorus, is satisfactory for such applications.

Improvement in ductility required to meet the conditions of processing was relatively small, nevertheless it was difficult to obtain in all heats of steel containing normal phosphorus. Individual heats, low in nitrogen (0.100% P), sometimes met the requirements but these were not reproducible in sufficient quantity, due to a lack of positive control of the nitrogen. Ductility requirements also vary somewhat with the type of mill. At the higher speeds, mills of three or four stands require softer and more uniform hot bands than five-stand mills.

In order to meet the demand for lower strength and hardness and greater ductility, all hardening elements had to be reduced. Carbon and manganese were first cut to practical operating minimums, followed by a reduction in the sulphur. The remaining elements to be considered were phosphorus, nitrogen and oxygen. Thoroughly deoxidized steels were developed for nonaging properties, but these killed steels are generally somewhat harder than the rimmed grades of the same analysis. It is difficult to produce a soft, nonaging steel suitable for sheets with satisfactory surface quality and a proper response to annealing at relatively low temperature.

These factors all tended to focus attention on reducing the phosphorus content of bessemer steel.

Successful Dephosphorizing

Existence of this field for lower phosphorus bessemer was recognized some years ago and several investigators have reported successful results in dephosphorizing the blown metal. Efforts were also made to produce a lower natural phosphorus steel by smelting raw materials very low in phosphorus in the blast furnace.

In 1937 Wheeling Steel Corp. developed and patented a dephosphorizing method best suited to our raw materials, shop equipment and the market we were serving. Since that time more than 1,000,000 tons of steel, under 0.050% phosphorus, have been made and put into products formerly made of openhearth steel, or applied as an improvement in certain other grades.

The first departure from former blowing practice had to do with the character of the converter slag. The available shop equipment did not permit us to reladle the blown metal to separate the siliceous slag, and therefore a thick and pasty slag was required so it would be held back in the converter as the blown metal was poured from under it into the steel ladle. It was found that the desired type of slag could be produced regularly by controlling the silicon and manganese in the iron. A ratio of 2.5 silicon to 1 of manganese, coupled with medium young blowing, produces thick pasty slags even in the higher ranges of blowing temperature. The slag is held back in the converter by inserting a block of wood inside the jaws of the vessel as it is turned down.

Dephosphorizing is accomplished by adding a mixture of lime, iron oxides and flux, all in the solid state, to the stream of blown metal as it flows into the ladle. (Ferromanganese is added at the same time.) The major portion of the phosphorus is removed in a few seconds by the basic oxidizing slag so formed, which is intimately mixed with the metal swirling about in the ladle; evolution of gas from the very hot blown metal also increases the agitation. Phosphorus is eliminated at the high temperature because of the very low carbon content of the blown metal and the absence of silicon. Ordinarily 50 to 70% of the initial amount present in the metal is slagged off, but greater percentages can be removed, if necessary, with special slag mixtures and improved equipment. Although iron oxides are present in the flux mixture and in the blown metal at the start of the additions, FeO in solution in the metal at the end of the blow is reduced approximately one-half when the reaction is completed. The proportion of iron oxide in the addition is adjusted to eliminate the desired amount of phos-

phorus and yet leave sufficient FeO in solution in the metal for proper rimming action in the molds.

The original mixture, when melted, contains about 50% CaO and 30% Fe_2O_3. After the reaction the slag volume is increased slightly by silica, alumina and manganese oxide. The final slags analyze about 45% CaO, 10 to 14% iron oxides (FeO and Fe_2O_3), 15 to 20% SiO_2, 4 to 6% Al_2O_3, 8 to 10% MnO and 5 to 6% P_2O_5. The final slag volume is about 3% of the weight of metal treated.

The metal is blown to a temperature of 3150° F. to provide excess heat to melt the cold addition. The photocell flame control aids in judging these high temperatures.

Physical Properties, As-Rolled

Low-Phosphorus Bessemer — A straight-line comparison, in the precise numerical terms usually expected in metallurgical procedure, of the two steels of low-phosphorus bessemer and basic openhearth steel of the same carbon and manganese contents at different phosphorus levels, cannot be made. Bessemer steel is greatly complicated by the presence of elements other than those usually specified, which have an important effect on physical properties. In unalloyed openhearth steel only carbon and manganese need ordinarily be considered in relation to the physical properties or as a guide in application.

In bessemer, relatively small changes in phosphorus content have a pronounced effect on physical properties of steels with increasing nitrogen, especially if rimmed and capped. In side-blown bessemer foundry practice the nitrogen is usually well below 0.008%; phosphorus up to 0.070% has little effect on aging and embrittlement in thoroughly deoxidized grades. In bottom-blown ingot practice the nitrogen is higher, varying from 0.010 to 0.018% in ordinary practice over a period of time, and the steel is usually rimmed or semikilled. With 0.010% nitrogen strong aging characteristics are shown at about 0.070% phosphorus in the open steel grades, and when nitrogen goes up to 0.018%, aging and embrittlement increase rapidly as the phosphorus in the steel goes over about 0.055%.

At any given level of carbon, manganese and nitrogen, increased phosphorus means increased sensitivity to aging and embrittlement. Phosphorus affects the cold workability and nitrogen increases the strain sensitivity.

These relations are based on trends observed during normal production, usual testing procedures, and final performance data for the products involved. Some further improvement in testing technique and analysis of data will be required to measure the influences in precise numerical terms.

The grades of steel included in this discussion are applied to a wide variety of flat rolled products classed as competitive commodities. Chemical limits and physical properties are not usually specified, and the steels are judged chiefly by performance.

On the basis of performance the 0.030 to 0.050% phosphorus bessemer steel has been established as a more ductile and more uniform final product than the grade with 0.100%. Reduction in the phosphorus and sulphur is sufficient to insure better cold workability, better response in annealing and processing generally, and less sensitivity to aging and embrittlement. Regular bessemer, converted to lighter gages by modern high speed cold reduction methods, has directional properties which cannot be eliminated by heat treatment at the usual relatively low temperatures.

Hardness — Rockwell hardness, as-rolled, is higher and varies over a wider range in low-phosphorus bessemer than low-phosphorus openhearth, but is lower and in a narrower range than in normal bessemer (0.100% P).

Elongation, an accepted measure of ductility, is lower and more variable for low-phosphorus bessemer than for openhearth but higher and less variable than for normal bessemer.

In the same section the average values for elongation in 8 in. are as follows in light gage, flat rolled material in the as-rolled condition:

0.030 to 0.050% P bessemer (capped)	28.5%
Rimmed low-phosphorus openhearth	30%
0.100% P bessemer (capped)	25%

Yield point is higher for a given ultimate strength in low-phosphorus bessemer than in openhearth but lower than in normal bessemer.

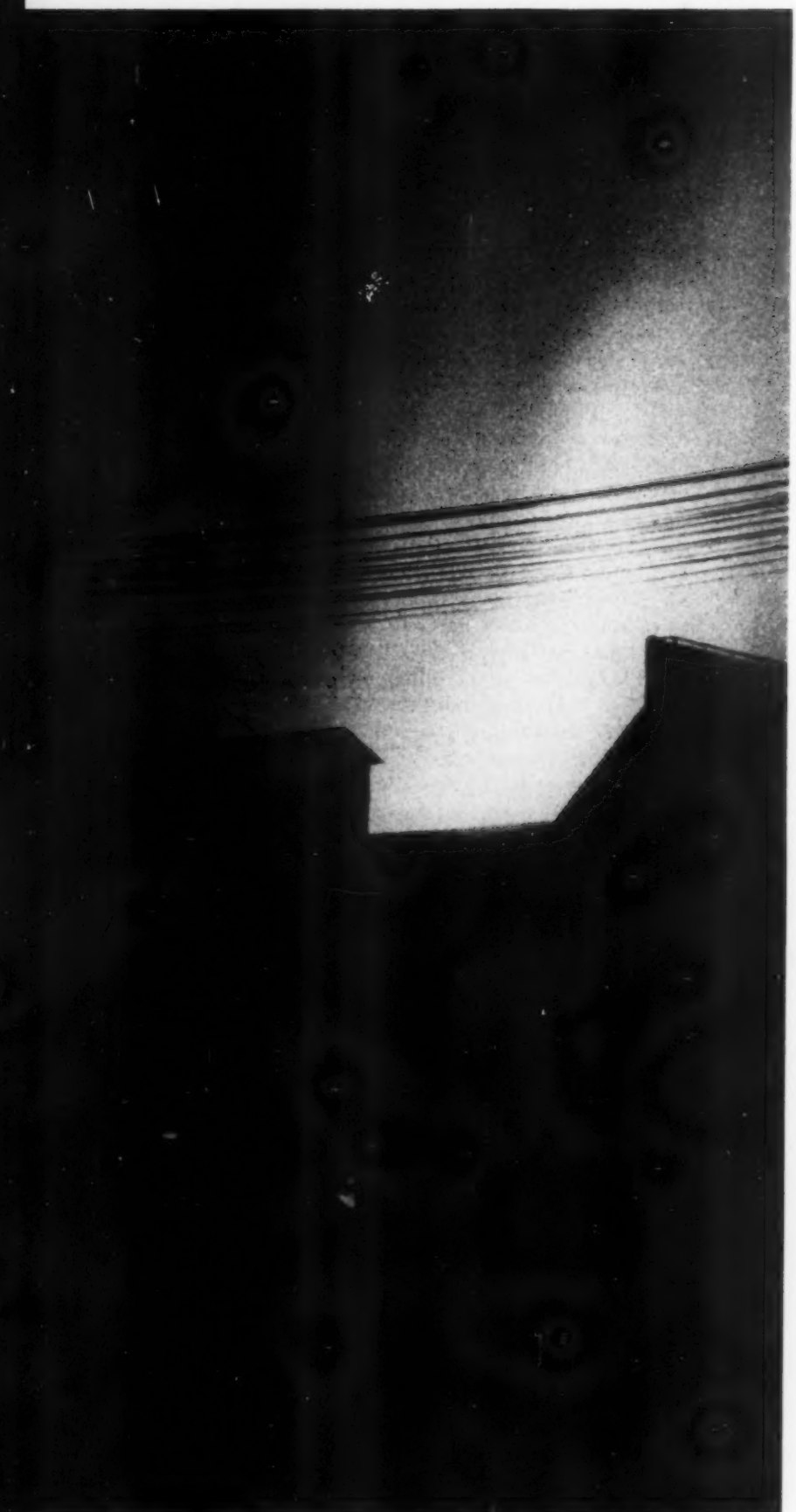
Ultimate strength is higher in low-phosphorus bessemer than in low-carbon, low-phosphorus openhearth, and lower than in normal bessemer (0.100% P). In comparison with low-carbon capped openhearth steel, the capped 0.030 to 0.050% P bessemer has physical properties similar to an openhearth steel with 0.070 to 0.080% P.

Approved Applications

The list of approved applications for dephosphorized bessemer is limited by the type of rolling equipment we have to flat rolled products and welded pipe.

Cold Reduced Products — In cold reduced sheets no attempts have been made to enter the openhearth steel's field of deep and extra deep drawing grades of any gage.

The major portion of the low-phosphorus



Photograph by Henry M. Mayer

steel available for the mild drawing and forming grades is rolled to gages of 0.009 in. (32 gage) to about 0.020 in. (25 gage). The largest application within this group is for 28-gage sheets for galvanizing followed by corrugating, V-crimping, and channel-drain crimping operations. In comparison with the regular bessemer its superiority is measured primarily by its ability to be cold reduced to this light gage at speeds competitive with openhearth steel. Regular bessemer will not meet these requirements.

The lower and more uniform phosphorus, especially its lower content in the segregated central zone in the ingot and hot bands, is the major factor in this performance. Second is the better response to annealing, which removes the directional properties better than is possible with normal bessemer — at least with limited furnace equipment. Finally, as to the finished product: The degree of work hardening and aging is reduced sufficiently to insure uniform corrugations and V-crimps and a very necessary high standard of flatness between crimps. Both grades of bessemer are very satisfactory from the standpoint of uniform spangle and tightness of coating.

Merchant Galvanized Sheets — The low-phosphorus bessemer is applicable to merchant galvanized sheets in gages of 18 to 30 (0.048 to 0.012 in.) inclusive. Normal bessemer has an extremely limited application in this group, due to lower performance of cold tandem mills when rolling the lighter gages, or a propensity to cracking in brake forming, mild drawing, or high speed lock-seaming operations in the heavier gages. During the transition from hot pack rolling to cold reducing methods, low-phosphorus bessemer was put without reservation into commercial galvanized sheets rolled from packs made from hot strip mill bands. Hot working and cross rolling contributed to the elimination of directional properties and reduction of strain sensitivity.

Black Plate — In this group low-phosphorus bessemer is applicable to light gages, 32 to 28 gage (0.010 to 0.015 in.). The requirements are uniform bending and forming quality in

either direction and mild drawing properties. The applications are bodies and shallow drawn bottoms for galvanized pails, tubs, garbage cans and various other containers. Compared with openhearth steel of the same gage and processed along parallel lines, the Olsen ductility values are about 8% lower and the hardness about 12% higher. Accelerated age hardening tests are about equal.

Blue Iron — The application in this group is in gages of 0.009 to 0.014 in. (32 to 29 gage) for fabrication of folded end pans and shallow drawn pans, drum heads and barrel heads.

As compared with openhearth of the same gage, processed along parallel lines, the Olsen values are lower and the hardness higher. Where both steels are processed to the same gage and temper rolled to the same Rockwell hardness, the 0.030 to 0.050% P bessemer shows lower elongations — for example, 25% for openhearth, 20% for low-phosphorus bessemer in 0.010-in. gage.

Building Materials — In this group, to mention a few, are channels, studs, partition bars, long span flooring, ridge roll, conductor pipe and trough stock. These are made from both hot and cold reduced stock of 0.015 in. (28 gage) to 0.110 in. (12 gage) thickness. The requirements are ability to withstand high-speed roll forming and a satisfactory stiffness in the finished product. Low-phosphorus bessemer is applicable to these materials without reservation.

Welded Pipe — In conduit pipe the bending moment of a 12-in. section is 98 lb. for low-phosphorus bessemer, 115 lb. for normal bessemer, and 85 lb. for low-phosphorus openhearth. After hot dip galvanizing the low-phosphorus bessemer has better ductility, lower hardness, and equal strength of welds when compared with normal bessemer.

It is also made into pipe grades for coiling and bending, such as for ammonia pipe and refrigeration plants, well tubing and some smaller sizes of boiler tube.

In electric welding the low-phosphorus bessemer is superior to the 0.100% P grade, since it has lower hardness, less strain and less grain growth in the area adjacent to the weld.

Quality

In any discussion of low- versus high-phosphorus bessemer steel the word "quality" creeps in, either stated or implied, when practically any comparison of physical properties is made. Quality, as applied to steel, has little significance except when considered in connection with the intended use. Sulphur, for example, is usually considered an undesirable impurity, but it is added intentionally to some grades for improving the steel's machinability.

With the exception of welded pipe, the products described here are benefited by low sulphur as well as low phosphorus. Sulphur is held to the desired level by a soda ash treatment as the iron is cast at the blast furnace, or when poured from the mixer (or a double treatment at the two locations when necessary). This control of sulphur is an additional tool for quality control in either the low of higher phosphorus grades; sulphur of under 0.040% can be produced in either where it is of benefit in the finished product.

Dephosphorization must be regarded in a similar manner — that is, all grades need not be dephosphorized. The treatment is applied only where lower strength and hardness and greater ductility are required. Where strength and rigidity are desired and the ductility requirements are not great the high-phosphorus bessemers still retain the field.

In some applications to consumers' goods, such as containers for various uses, the low-phosphorus bessemer has certain advantages over the openhearth grade. Ductility is sufficient to withstand fabrication, and the final product has a desirable stiffness and rigidity to resist collapse during rough handling. This property of stiffness, coupled with satisfactory ductility, makes it possible to produce certain articles in a lighter gage than when made of openhearth steel.

The added stiffness is also of benefit in the final cold temper rolling of annealed cold reduced plate. Openhearth plate, for example, may require 5% cold reduction to obtain the desired properties, but the same requirements may be met with low-phosphorus bessemer with as little as 2%.

Due to the oxidizing nature of the dephosphorizing slag, this process has been restricted to the making of low-carbon grades of steel. Reladling is required for the higher manganese and carbon grades in the fully deoxidized condition.

The new process contributed to the war effort in many ways which were limited only by the capacity of the plant. Bomb fins, bomb fin crates, landing mats and the like were direct applications. In the wide field of consumers' goods it is applicable to many articles of everyday use, and so released an equivalent tonnage of openhearth for ordnance.

This grade of bessemer steel is applicable to many items other than the flat rolled products described in this article. There is a large field for it in rods, wire, and cold drawn bar stock. In products where a certain balance of free machining stiffness and cold working properties are required, it should find a wide application.

A MODEL WHICH SHOWS HARDENING AND ANNEALING MECHANISMS

By EDWIN C. DAVIS

Assistant Professor of Metallurgy, Virginia Polytechnic Institute, Blacksburg, Va.

ONE DAY, while playing (perhaps "doodling" is the word) with a number of lead shot placed in a watch glass, I noticed that when the glass was slowly tapped the balls had a tendency to rearrange themselves in orderly rows. The thought went through my mind that the shot were atoms and here was an excellent way to demonstrate the processes of slip, slip interference, cold work and annealing.

I thereupon experimented with various sizes and curvatures of watch glass, various sizes of shot, and different methods of agitating the glass to produce the best results. Later, the watch glass was placed on the table of a Balopticon so that the image could be projected on a screen and it was used for a very effective classroom demonstration.

As a result of trials, it was determined that when a watch glass 2 in. in diameter was used in combination with $\frac{1}{16}$-in. balls, a suitable pattern for projection was obtained. Although regular BB shot could be used in a 3½-in. glass and give good results, it was impossible to focus the complete image on the screen.

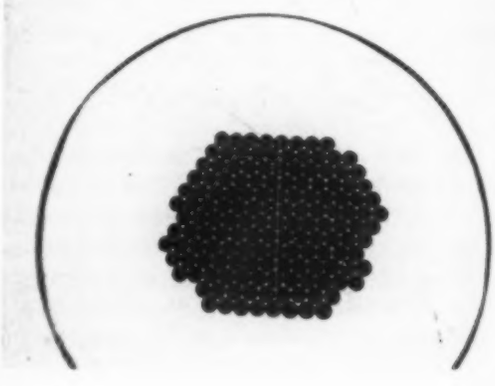
The orderly arrangement of shot shown in Fig. 1 represents the planar arrangement of atoms in a single crystal or grain, free of strain. The lattice is undistorted, and the slip planes are clearly defined. A metal with such a space lattice would be soft and ductile, and in this condition it would be similar to annealed material.

Now, if a finger is rolled over the surface of the shot the previous orderly arrangement is destroyed. This movement of the balls (atoms) under the finger is analogous to the movement of atoms within the grains during plastic deformation, although actually this stirring action is not exactly the way movement of the atoms takes place. The resulting structure, as shown in Fig. 2, now shows a distorted heterogeneous arrangement of atoms in the space lattice, with no definite slip planes of any extent — analogous to the structure induced by severe cold working. The area of voids in Fig. 2 is clearly seen to be greater than the area of voids in Fig. 1, which demonstrates the increase in volume, or decrease in density resulting from cold work.

With the balls still in a disorderly arrangement, the watch glass may be given a circular motion such that it rolls under shot, thus giving them increased mobility. This is analogous to raising the temperature of the material. The action within the watch glass represents the principle that increased thermal agitation of the atoms allows increased mobility, which is the mechanism of the process of annealing.

During this manipulation of the watch glass it is possible that several distinct grains may be formed which, upon continued agitation, will finally resolve themselves

Fig. 1 — Lead Shot in a Watch Glass Arranged in Orderly Rows and Ranks Like a Space Lattice



into a single grain of the form shown in Fig. 1. It can readily be seen that this is analogous to what takes place under the condition of continuous heating at the annealing temperature or during annealing at high temperature, either of which is conducive to grain growth with its resulting coarse-grained structure. Actually, under the conditions on the watch glass, as in actual practice, the larger grains grow at the expense of the smaller grains.

A demonstration of the reason why fine-grained material is harder, and consequently has a higher tensile strength than coarse-grained material, can be observed in either Fig. 3*a* or 3*b*. These figures illustrate how slip planes of one grain are continually being interfered with by both grain boundary material and by the slip planes of the adjacent grains, differently oriented; this obviously limits the deformation within any single grain.

It is possible to demonstrate the increase in hardness

Fig. 4 — Slip Planes in Fig. 1 Disarranged by Insertion of a Large Atom (Analogous to the Hardening by Solid Solution)

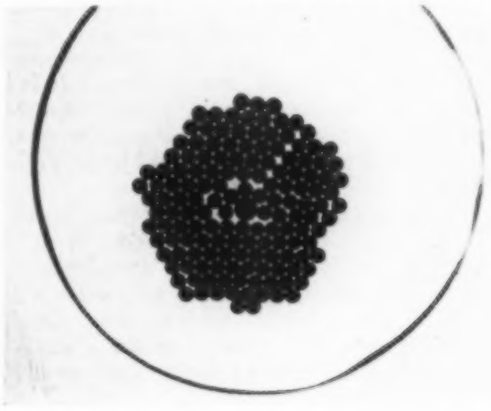
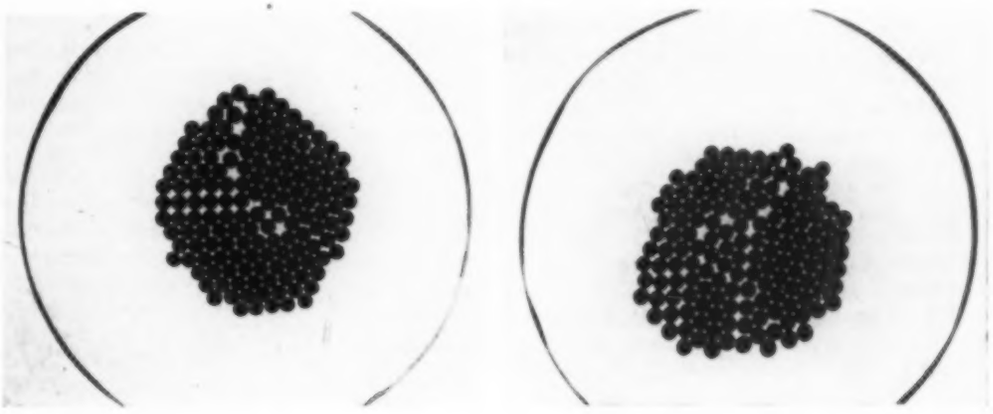


Fig. 3a and b — Partially Recrystallized Structures Derived From Fig. 2 by Merely Twirling the Watch Glass (Simulating High Temperature or Annealing Effects)



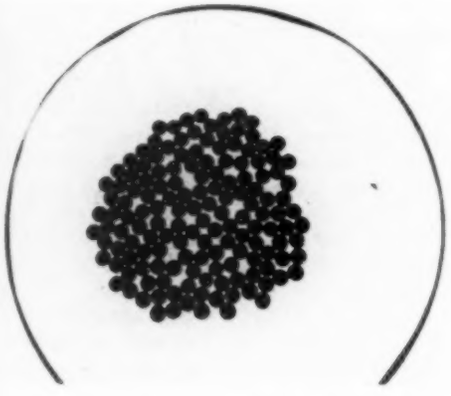


Fig. 2 — Disorganized Arrangement Showing Conditions in a Heavily Cold Worked Metal

of solid-solution type alloys, where an atom of larger physical dimension is substituted for one of the regular ones in the ordinary space lattice, by placing one or more shot of a larger size in what would ordinarily be a single annealed grain. The resulting distortion and consequent resistance to slip along the roughened slip plane is at once very apparent, as can be seen in Fig. 4.

(While the substitution in the space lattice of a replacement atom of *smaller* volume than the atom it replaces will also cause distortion of the slip planes, this cannot be demonstrated by this method; the smaller shot merely lies in the space formerly occupied by the ordinary shot. The arrangement of Fig. 4 may also be regarded as representing the disorganization of atoms — and slip interference — caused by the appearance of a tightly bound group of atoms such as a few molecules of a metallic carbide, or an intermetallic compound, or the first stages of precipitation hardening.)

Occasionally as many as four grains will form while agitating the heterogeneous arrangement of the balls upon the watch glass, although such results cannot be obtained at will. Even three grains form but seldom. It is, however, surprising to see how simple it is to "anneal" several grains (Fig. 2) to a single grain (Fig. 1) by just agitating the watch glass.

Comments others may have regarding the effectiveness of this demonstration will be appreciated by the author.

The Decision to Use the Atomic Bomb

IN *Harper's Magazine* for February, Henry L. Stimson, secretary of war from 1940 to V-J day, and at all times the President's senior adviser on the military employment of atomic energy, presents his personal observations of the circumstances which led up to the use of the atomic bomb. It is a document of exceptional importance. Space limitations exclude mention of the international politics of the problem, considered by our government prior to the use of the bomb. Brief excerpts follow:

It was our common objective to be the first to produce an atomic weapon and use it. It was considered to be a new and tremendously powerful explosive, as legitimate as any other of the deadly explosive weapons of modern war. In the spring of 1945 it became evident that the climax of our prolonged effort was at hand, and we must consider the implications of success in terms of its long-range postwar effect.

On April 25, 1945, I discussed with President Truman the whole history of the project, as well as its broader aspects, and steps were taken to establish a select committee of particular qualifications for recommending action to our government when secrecy is no longer in full effect.★

On June 1, after its discussions with the scientific panel, the interim committee adopted the following recommendations: *(a)* The bomb should be used against Japan as soon as possible; *(b)* it should be used on a dual target — that is, a military installation or war plant surrounded by other buildings most susceptible to damage, and *(c)* it should be used without prior warning of its nature.

Such alternatives as a detailed advance warning or a demonstration in some uninhabited area were discarded as likely to be ineffective in compelling a surrender of Japan, and as involving serious risks of a dud. Furthermore, we had no bombs to waste.

The conclusions of the committee were similar to my own, although I reached mine independently. I felt that to extract a genuine surrender from the Emperor and his military advisers, they must be administered a tremendous shock which would carry convincing proof of our power to destroy the Empire. Such an effective shock would save many times the number of lives, both American and Japanese, that it would cost.

[Then follows a discussion of the U. S. policy toward Japan in early 1945, with the decision by President Truman that Japan was to be issued an ultimatum from the Potsdam conference, July 26] so it would be plain that *all* of Japan's principal enemies were in entire unity. It is important to emphasize the double character of the warning. It was designed to promise destruction, if Japan resisted, and hope, if she surrendered.

On July 28 the Premier of Japan, Suzuki, rejected the Potsdam ultimatum. We could only proceed to demonstrate that the ultimatum had meant exactly what it said when it stated "the full application of our military power, backed by our resolve, will mean the inevitable destruction of the Japanese armed forces and just as inevitably the utter devastation of the Japanese homeland."

For such a purpose the atomic bomb was an eminently suitable weapon.

Hiroshima was bombed on August 6, and Nagasaki on August 9. These two cities were active working parts of the Japanese war effort. Hiroshima was the headquarters of the Japanese Army defending southern Japan and was a major military storage and assembly point. Nagasaki was a major seaport and it contained several large industrial plants of great wartime importance. We believed that our attacks had struck cities which must certainly be important to the Japanese military leaders, both Army and Navy. These two atomic bombs were the only ones we had ready, and we waited for a result. . . . . We waited one day.

Two great nations were approaching contact in a fight to a finish. Our enemy commanded forces of somewhat over 5,000,000 armed men. Men of these armies had already inflicted upon us, in our breakthrough of the outer perimeter of their defenses, over 300,000 battle casualties. Enemy armies still unbeaten had the strength to cost us a million more. As long as the Japanese government refused to surrender, we should be forced to smash the Japanese ground armies, by close-in fighting of the same desperate kind that we had faced in the Pacific islands.

My chief purpose was to end the war in victory with the least possible cost in the lives of the men in the armies which I had helped to raise. In the light of the alternatives which were open to us, I believe that no man, subject to our responsibilities, holding in his hands a weapon of such possibilities for accomplishing this purpose and saving those lives, could have failed to use it. The decision to use the atomic bomb was a decision that brought death to over 100,000 Japanese. No explanation can change that fact. But this deliberate, premeditated destruction was our least abhorrent choice. It stopped the fire raids†, and the strangling blockade; it ended the ghastly specter of a clash of great land armies.

In this last great action of the second world war we were given final proof that war has grown steadily more barbarous, more destructive, more debased in all its aspects. Now, with the release of atomic energy, man's ability to destroy himself is very nearly complete. The bombs dropped on Hiroshima and Nagasaki ended a war. They also made it wholly clear that we must never have another war.

This is the lesson men and leaders everywhere must learn, and I believe that when they learn it they will find a way to lasting peace. There is no other choice.

★This "Interim Committee" consisted of Henry L. Stimson, chairman, George L. Harrison, vice-chairman, James F. Byrnes, Ralph A. Bard, Wm. L. Clayton, Vannevar Bush, K. T. Compton and J. B. Conant. This committee was assisted by a scientific panel whose members were A. H. Compton, Enrico Fermi, E. O. Lawrence and J. R. Oppenheimer.

†In March 1945, our air force had launched its first great incendiary raid on the Tokyo area. In this raid more damage was done and more casualties were inflicted than at Hiroshima.

The research division of the National Board of Fire Underwriters and the engineering staff of the Factory Insurance Association have studied the contributory factors responsible for the majority of incidents (fires, explosions, personal injuries) reported involving molten salt baths used for heat treatment. Their report should be of interest to operating metallurgists.

POTENTIAL HAZARDS IN MOLTEN SALT BATHS FOR HEAT TREATMENT

From Research Report No. 2, The National Board of Fire Underwriters

MOLTEN SALT BATHS have been in the "special hazard" classification of insurance groups for a considerable time. The leading manufacturers of salt bath equipment and supplies have been aware of the operational hazards, and considerable progress has been made toward eliminating them.

The probability of fires and explosions in the low-temperature neutral baths is greater than in processes using medium or high-temperature baths. This is due principally to the fact that the salts for low temperature usually consist of nitrate and nitrite compounds. Such mixtures are powerful oxidizing agents, and in the molten state they become very highly active, and consequently require greater care in handling. Furthermore, if heated above 1100° F. the nitrates attack the metal of the container, and at 1300° F. and above, the salts are subject to rapid breakdown with emission of toxic and reactive fumes, the oxides of nitrogen.

Medium-temperature baths are usually eutectic mixtures of chlorides, carbonates and cyanides, and do not present the same hazards as the low-temperature baths. However, the use of cyanides calls for special operational safeguards, as they are extremely toxic and emit toxic fumes when brought in contact with acid mediums. They will combine with nitrates with explosive violence in the molten state.

High-temperature baths consist of a number of mixtures of barium chloride, borax, sodium fluoride, silicates and magnesia or lime. Heat treatment at high temperatures is an exacting operation and accurate control is most important. It is desirable to preheat the work before immersion into the high-temperature baths, and the low and medium salt bath operations are used for this.

In establishing an efficient and safe molten salt bath process, the choice of the container is very important. These containers are fabricated either from iron alloys or ceramic materials. The composition of the steel pots varies from cast iron and low-carbon steels to corrosion resistant high-chromium and nickel alloys. Steel pots used for low-temperature nitrate baths are subject to more corrosive fumes and chemicals than pots exposed to other salts, and therefore special corrosion resistant steel alloys have an advantage in this application over low-carbon steel. Reactions between the salt and pot often cause excessive scaling which leads to the possibility of uneven and local overheating.

Ceramic containers are used only in conjunction with baths heated electrically through immersed electrodes. Ceramic pots are usually made of refractory materials consisting of silica, oxides and silicates of magnesium, calcium and aluminum. These substances are subject to decomposition in contact with alkaline salts.

As this equipment is used under extreme conditions and at high temperatures, the useful span of life has been brief and often indeterminate. It is recommended that externally heated pots holding nitrate baths be emptied, cleaned and examined at least once every six months.

The design and choice of furnaces are extremely important from the standpoint of safe

operating conditions. It is essential that local overheating be avoided and, therefore, a flame should never impinge or bear directly upon the container's wall. Coal-fired furnaces are rarely used and are strongly advised against, due to the lack of proper heat control and the most dangerous reaction of the molten nitrates with carbonaceous materials in the event of pot failure. Flames in gas and oil-fired installations should be properly adjusted to avoid soot formation. To prevent explosive gas and air mixtures if the flame is snuffed out, a quick action shut-off valve should be handy to the operator. Leakage of stray currents in electrically heated units may lead to electrolytic corrosion and contribute toward the perforation of the pot wall.

While oil-fired furnaces, gas-fired furnaces, electric resistance furnaces and direct resistance electrode heaters are in general use, the present trend seems to be toward the use of the direct resistance electrode heaters. Some of the important points of salt bath furnace design are listed in "A.S.M. Metals Handbook", 1939 edition, p. 320 [revised and expanded in the forthcoming edition].

Molten salt baths require accurate and reliable temperature controls to insure the proper operation of the process. An adequate number of thermocouples should be located in large pots so as to catch all possible hot spots. It is also usually desirable to have an additional control for safety purposes which automatically shuts off the heat when the temperature exceeds the operating range.

The hazards which are prevalent in the molten salt bath process may be divided into three main classifications:

1. Fire by contact of molten salts with combustibles.
2. Explosion through chemical and physical reactions.
3. Physical danger to the operator:
   (a) Exposure to gassing.
   (b) Burns by molten salts.

The possibility of fire is present in all phases of the molten salt bath operations. The salts are worked at temperatures ranging from 300° F. to 2400° F., and contact of the heated salts with any combustible material will cause a fire. Records show that the sudden ejection, accidental spilling, popping or spattering of the hot salts have produced fires of greater or lesser importance.

Explosions have also occurred in the operation of molten nitrate baths. Nitrates will react and start a brisk combustion process at 1100° F., a danger particularly prevalent under poor furnace conditions and when sludge or sediment is allowed to accumulate in pots heated externally through the bottom. Devastating explosions have resulted from inadvertent dipping of magnesium castings. Nitrates will also react with aluminum alloys containing small amounts of magnesium when a critical temperature is exceeded. Most authorities advise against heat treating in such a bath aluminum sand or die casting alloys such as No. 220-T4 and 218 containing 8 to 10% Mg.

Heated nitrates react strongly with all free or chemically combined carbonaceous material such as oil, soot, tar, cotton waste, graphite or cyanides. Most of these materials will be found in the operating room by virtue of their use in some other integral part of metal heat treatment. Accidental mixtures of cyanides with molten nitrates have caused explosions of considerable violence with tragic and serious losses. The accidental injection of a quantity of water into the molten bath may result in an instantaneous generation of steam, and cause a serious explosion or fire. Explosions have also occurred when air trapped in closed metal tubing or in casting cavities and blowholes undergoes rapid expansion in the molten salt bath.

Intensive external reheating and remelting of the solidified or frozen bath may result in rapid expansion sufficient to cause the bath to bulge and became dangerously strained, or enough pressure may be generated in the bottom to break the salt crust suddenly and scatter the fused materials. To avoid such injurious overheating, starting coils and low voltage transformer taps have been used, or long steel wedges placed in the bath vertically before solidification to provide vents.

Safety provisions must be made for the operators. The nature of the work indicates that most injuries to persons working with this process are caused by burns by molten salts. Protection to clothing is essential, since ordinary garments will catch fire when contacted. Work garments should not be allowed to become impregnated with nitrate salts. Spatter of hot liquid salts on the body may result in dangerous or even fatal burns.

Good ventilation is essential to prevent accidental gassing by nitrous fumes. Nitrates and nitrites may break down when undergoing chemical reaction and form injurious gases. These gases may be visible as reddish-brown fumes in high concentrations or may be obscured by smoke in low concentrations. The fumes are very dangerous, and their insidious or delayed action eliminates the usual warning signals given by some other gases. Good practice requires the installation of ventilators over the baths and gas masks should be available for an emergency.

A schedule of recommended precautions based on the above observations and an analysis of recorded incidents, is given on the next page.

Precautions Recommended for Molten Salt Baths

From Research Report No. 2 (M 65), National Board of Fire Underwriters, 1946

Shop Construction and Layout

1. Room should have two-hour fire resistance, be free from automatic sprinklers, have a leakproof roof and contain a minimum of combustible material. Wooden flooring, platforms and benches should not be permitted in the vicinity of baths.

2. Plenty of room about the bath is essential. When work requires a water or oil quench bath in the close proximity, it should be located at a lower level and fitted with deflecting baffles or guards to prevent accidental splash-over.

3. All water conveying devices should be in such a position that leakage into a molten salt bath is impossible.

4. To disperse the heat and prevent the accumulation of deleterious fumes, baths and their furnaces should be installed in a room where ceiling is 20 ft. over the top of furnaces. When quarters are confined, a hood equipped with wire screen to catch loose deposits and accumulations should be placed over the bath.

Storage of Nitrate Salt

5. Nitrate salt should be stored away from heat and other reactive chemicals in a separate building. It should be added to the bath immediately after being brought in to the heat treatment department.

6. Salts should be stored in tightly covered drums to prevent moisture pick-up and contents of drum and pot should be carefully labeled to prevent accidental explosive combination of salts.

Housekeeping

7. All combustible materials should be kept away from baths. Make-up additions should be made from metal containers; sacks and paper bags should be avoided.

8. Waste nitrates and bath residues should be discarded in water solution, not burned.

Equipment and Controls

9. Unburnt fuel should be disposed of safely, and burners should be inspected and adjusted regularly to reduce soot formation.

10. Two independent automatic temperature control systems will help to eliminate any danger of overheating. A wise notice to be placed over nitrate baths would read "DO NOT PERMIT TEMPERATURES ABOVE 1000° F."

11. When a nitrate bath is not attended, its cover should be closed and the switch on the heating circuit thrown to idling position.

12. Avoid using coal for heating nitrate baths. The furnace should be built to prevent the possibility of uneven or local overheating. Direct flame impingement should be avoided. Emergency storage, in the form of some device or baffles to prevent molten salt from spreading over the work floor or cellar floors, should be provided to operate in event of bath failure.

13. Nitrate bath containers should be inspected regularly and electrodes and heating units examined. Chromium-nickel containers are recommended.

Operating Requirements

14. Hooks, fixtures and ladles used in one bath must be thoroughly washed and dried before using in baths of other nature. Avoid getting extraneous matter in any bath.

15. Material drawn from quench tanks should be preheated to drive out moisture before immersion in molten salt bath.

16. Tools of solid construction should be used, and hollow or tubular articles should not be inserted in the bath unless they contain air vents.

17. Do not leave articles in bath after they are supposed to be withdrawn. Sludge and small metal articles in the bottom of the bath will cause overheating. A chromium-nickel wire basket hung near the bottom will facilitate the recovery of small parts.

18. Care should be exercised to prevent accidental immersion of magnesium or its alloys.

19. If overheating of nitrate bath occurs:
   - *(a)* Shut off heat supply to the furnace.
   - *(b)* Remove all work from the bath.
   - *(c)* Get all employees to a safe location away from bath.
   - *(d)* Recheck bath temperature and if it continues to increase, prepare for an explosion.
   - *(e)* Call the fire department and briefly explain the situation.
   - *(f)* Summon plant fire brigade for emergency standby.
   - *(g)* Open windows.

20. Do not remelt cold bath with heat at bottom of pot unless wedge vents are provided. Top heating or immersion electrode heating is best.

Supervision

21. Workers at salt baths should wear safety clothing and gas masks should be available. A 1 to 2% boric acid solution should be provided in convenient cabinets for treating burns.

22. Molten salt baths should be supervised by qualified personnel.

23. Instructions on the operation of salt baths should be conspicuously placed.

Fire Protection

24. Buckets of sand should be placed near bath. They are best for slagging and diking purposes if salt spills or leaks. Signs warning against the use of water in case of fire should be posted. No foam extinguisher or others containing vaporizing compound (carbon tetrachloride) should be permitted in the building. Fires in wood or other carbonaceous material can be quenched with carbon dioxide or approved dry powders.

25. Warning of the presence of salt baths should be posted on the outside of the building, and the local fire department should be kept informed of their locations and the hazards.

THE MOMENT OF ACTIVE DEFORMATION

By HARRY L. STRAUSS, JR.
National Diamond Hone and Wheel Co., New York City

THIS SHORT NOTE treats of the rather singular phase of powder metallurgy known as hot pressing. The conventional technique of first pressing a compact mass of powder in a closed die hard enough to assume the form of an adherent mass, and then subsequently sintering this compact in a reducing atmosphere is one that has received much attention from metallurgists and industry in general. Design of pressing dies and lubrication techniques have also received their share of comment from the technical journals. But the method, which in the author's opinion carries the greatest potential use, is hot pressing — meaning the formation of an accurate, strong part from powder metals (or mixtures with nonmetals) by using heat and pressure simultaneously.

Hot pressing will receive a great stimulus from now on as we get more interested in the use of hard carbides and borides and refractory materials in a multitude of exacting services, since some of them can only be fabricated commercially by hot pressing. Even in the making of metallic parts, densities are improved and sintering time reduced to seconds. Densities can be held to reasonably uniform limits in odd shapes and in their extremities — in contrast with the conventional methods by which a part sometimes could not even be made, because certain important portions would be less dense than the main cross section.

Hot pressing is being used by the author, and has been for the past three years, to hold hard, nonmetallic bodies in a secure manner. By proper use of this method we can now guarantee our settings of industrial diamonds from working loose in the tool or holder. The information below, based in good part on this successful commercial operation, is believed to be new and important data that will aid others to construct machines for hot pressing in production.

Certain physical phenomena occur while heated metallic powders are subjected to pressure, about which little or nothing has been published up to this time. It is a characteristic of nearly all

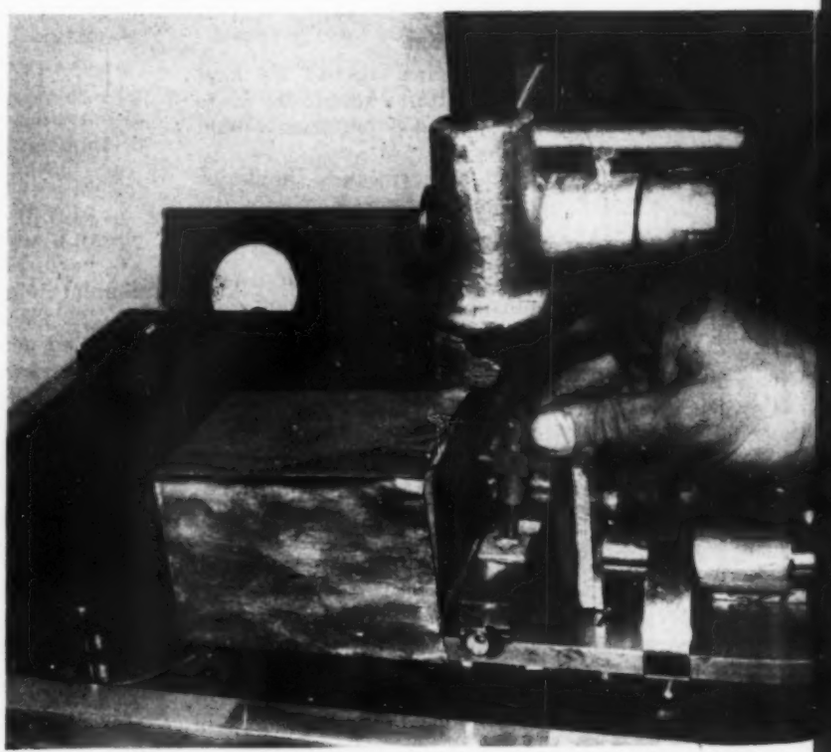


Fig. 1 — Laboratory Setup for Hot Pressing in a Carbon Die Heated by Electrical Resistance

metals, many nonmetals and certain refractories that when they are undergoing pressure and heat at the same time there is a rather sudden contraction of the volume. Apparently there is a period when the time and temperature are such that it is physically possible for the material to assume suddenly a degree of plasticity that is totally unobtainable in general conventional cold-press practices (a pressing operation and subsequent sintering in a reducing atmosphere).

Table I — Comparative Working Pressures

Metal	Hot Pressing	Conventional Cold Pressing
Tin	350 psi.	6000 psi.
Aluminum	200	8000
Bronze, annealed	600	8000
Brass	500	8000
Carbides	1200	20,000

Table II — Working Data, Hot Pressing Versus Conventional Methods

Metal	Hot Press			Conventional Sintering After Pressure	
	Melting Point	Working Temperatures	Working Time Cycle	Working Temperatures	Working Time Cycle
Aluminum	1215	800° F.	45 sec.	900° F.	15 min.
Bronze	1850 ±	1550	45	1650	30
Copper	1980	1600	45	1750	30
Cu-Ni-Sn (75-8-17)	2200 ±	1600	40	1850	30
Nickel	2645	1800	45	2000	30
Tin	450	340	45	380	30
Silver	1760	1450	45	1580	30
Tungsten carbide	—	2450	45	2600	60

Figure 1 shows the first laboratory device used by the author for the hot pressing of metal powders. Note the carbon die being nested between the two small round electrodes extending horizontally, and the two vertical plungers emanating from the die — one projecting downward and resting on the small anvil and the other projecting upward to receive pressure from the arbor press plunger. (The author would welcome any reader comment as to a better die material than carbon blocks.) Pressure in this simple device is adjustable and is had by slipping a lever arm through the hole in the shaft actuating pinion gear and rack (in this equipment the ram of the small arbor press). For preliminary experiments pressure is applied by man power; for precision the lever is replaced by a pulley, belt and weight pan. Heat is supplied by electrical resistance, the current passing through electrodes and carbon die from energized terminals on either end.

Pressure can be applied in this device at a constant amount following any drop or increase in density that occurs during the operation. By taking advantage of what the author calls "the moment of active deformation", or plastic stage, the very light pressures shown in Table I are all that need be used for getting a very dense compact, and the speed is remarkable — a matter of seconds!

A definition of the "moment of active deformation" of hot plasticity is as follows: "When time and temperature have approached a point where it becomes physically possible for the material involved to undergo plastic deformation, its density markedly increases in a very short time; this is known as the moment of active deformation."

As a result of our tests we find that the temperature of such active deformation in °F. is approximately one-third the melting point of that metal, also expressed in °F. More precisely, three groups of metals are recognized — *(a)* fusible, *(b)* ordinary and *(c)* refractory — and for them the following formulas are suggested to determine at what temperature this noticeable stage of rapid deformation will occur:

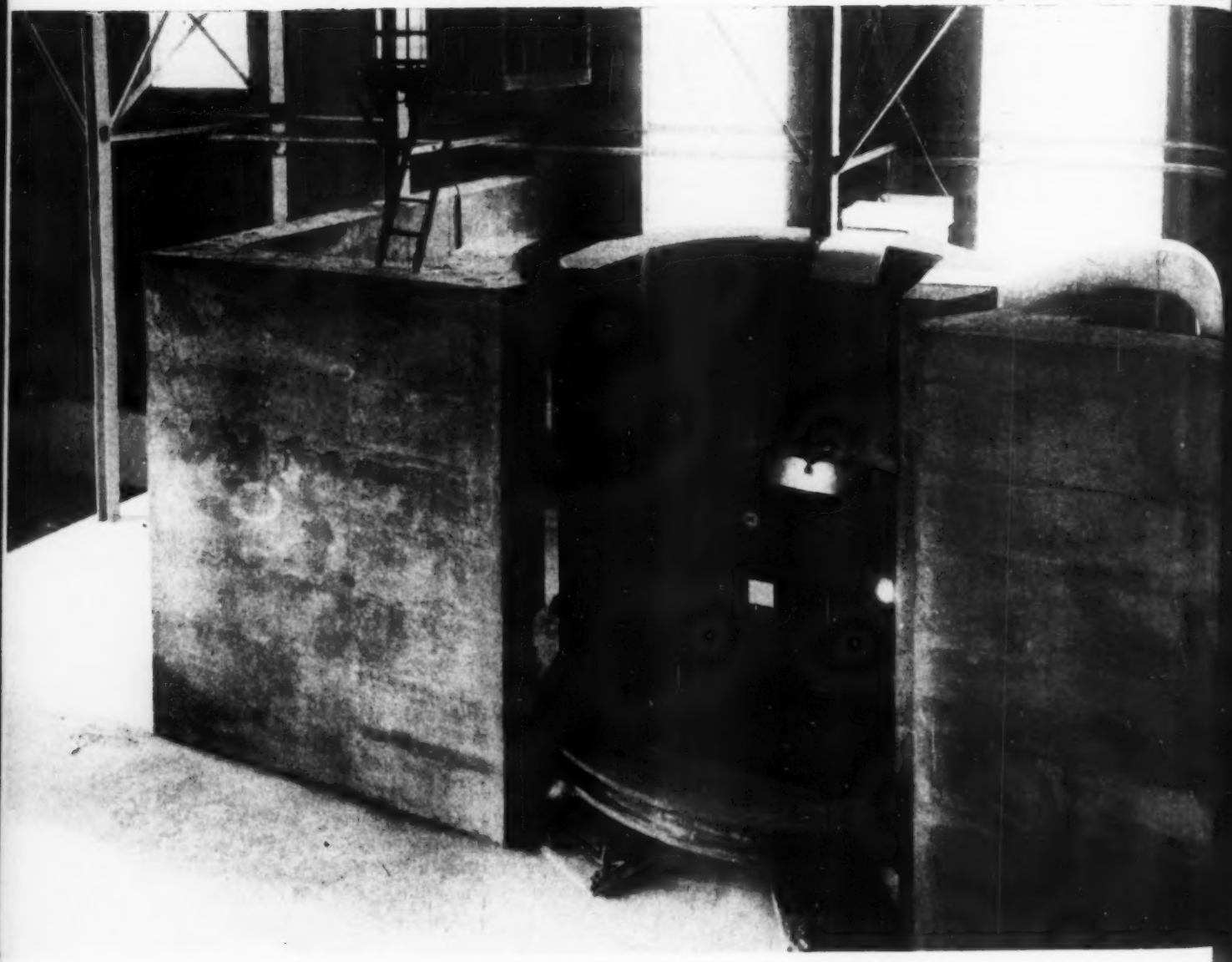
M.P.	Active Deformation
< 500° F.	M.P. ÷ 2.7
500 to 1000° F.	M.P. ÷ 3.0
> 1000° F.	M.P. ÷ 3.4

The above figures are of course only to be used as a guide for more precise experimentation.

This observation of the rapid compaction of metal and other powders at moderate temperatures and pressures is given without speculating as to its physical causes. A satisfactory explanation, acceptable to scientists, will have to await a lot of confirmatory and precise evidence.

In our own manufacturing operations, the moderate pressure on powder compacts is maintained while the temperature is carried considerably higher. However, as will be shown from an inspection of Table II, the final temperature is about 200° F. lower than the ordinary sintering temperature for cold pressed compacts, and the total time in the working cycle is a small percentage of conventional practice.

Courtesy Allis-Chalmers Mfg. Co.



Betatron at Picatinny Arsenal

A 2,000,000-volt X-ray unit at Elwood Ordnance Plant for radiographing loaded shells was described in *Metal Progress* for February 1946. Another device for producing an even more penetrating X-ray with large amounts of the most desirable range of energies for heavy steel inspection (near 8,000,000 volts) is produced by the "Betatron", developed during the war at the University of Illinois. A 20-million volt machine of this sort, built by Allis-Chalmers Mfg. Co., has recently been installed at Picatinny Arsenal. It is shown in the half-tone within its concrete shield walls and surrounded by the ring that will carry the shells being radiographed. The betatron operates from 25 kw. of 180-cycle alternating current at 5000 volts, supplied from a 60-cycle, 440-volt line. In each cycle — 180 per sec. — a short burst of electrons is emitted from a vacuum-tube filament; these electrons are spun around and around about 350,000 times, in a doughnut-shaped tube placed within the poles of an electromagnet, acquiring an energy of 20 million electron volts and a velocity almost that of light; an auxiliary turn of the magnet is then energized, allowing these speeding electrons to circle outward and strike a platinum target; this impact generates a cone-shaped beam of X-rays (180 pulses each second) which proceed in a direct line with the electron beam. The effective target is less than 0.010 in. wide, thus giving nearly a point source and a high order of definition on radiographs; flaws 0.060 in. in size may be detected in 18 in. of steel at any depth. Loaded 10-in. shells are inspected at the rate of more than 60 per hr.

The advantages of a well designed temperature control system for plating are: Improved quality and uniformity of the work; reduced plating costs; increased production; savings in steam and cooling water. By operating at the most efficient temperature and current density, quality is improved, rejects become fewer, and plating speed can be increased to maximum.

BRIGHT CHROMIUM PLATING AND TEMPERATURE CONTROL

By M. G. HERBACH and C. W. BOWDEN, JR.
Philadelphia Rustproof Co. and Brown Instrument Co., Philadelphia

CHROMIUM PLATE is characterized by its extreme hardness and resistance to tarnish. These properties are utilized commercially for protection against wear and for applying a decorative finish to metal surfaces. However, the plating baths are much more sensitive to changes in operating conditions than are any of the other commercial electroplating solutions. Since the temperature of the bath affects most of the other variables of the chromium plating process, temperature control is highly important in producing satisfactory work.

Types of Chromium Plate — As is well known there are two recognizably different types of chromium plate for two different fields of application. One, known as hard or industrial plate, is used to protect gages, tools, dies, and similar equipment from excessive wear. It is usually deposited on a hard steel surface to a thickness of 0.0005 to 0.0080 in. There need be no additional protection of the basis metal under these hard or friction resisting deposits.

The second type of plate, known as decorative plate, is used for its appearance and tarnish resistance. This is the type familiar to the public. It is characterized by the blue-white, bright surface so widely used on automobile parts and on domestic hardware. Decorative chromium deposits, usually between 0.000013 and 0.000025 in. thick, are somewhat porous; therefore they are applied over a tight nickel underplate intended to prevent the basis metal surface from rusting.

Preparation for Plating — Since chromium electrodeposits generally reproduce the underlying surface, it is important that the part to be plated be smooth and free of scale or imperfections. Thus it is frequently necessary to grind or polish the article prior to plating. However, a well finished article such as some die castings or fine machined pieces can sometimes be plated without any surface treatment other than cleaning.

Before a satisfactory deposit of chromium can be applied to any object, the surface must be scrupulously clean. Heavy coats of oil or grease can be removed by solvent or vapor degreasing, but to destroy the last traces of oily materials, the articles should be thoroughly cleaned in a hot alkaline bath.

The cleaner, operated just below boiling, usually consists of caustic soda, trisodium phosphate, and soda ash dissolved in water. Cleaning is sometimes accomplished by first electrolyzing the work as a cathode, then as an anode, in an alkaline solution consisting of caustic soda, trisodium phosphate, and borax maintained at approximately 150° F. There are numerous proprietary cleaners available which, when used according to manufacturers' recommendations, operate very satisfactorily.*

*See an article by Samuel Spring and Louise F. Peale ("On the Mechanism of Metal Cleaning") in *Metal Progress* for January, page 102.

Although alkaline cleaners remove all foreign surface contamination, they leave an oxide film on metal objects, which interferes with the electrodeposition of chromium. The film can be removed in an acid dip; it also very slightly roughens the surface, thus improving the adherence of the deposit. Both dilute and concentrated acid solutions are used at room temperature with and without electrolyzing the work.

Bright nickel-plated objects which do not require buffing prior to chromium plating can be plated without cleaning, other than a thorough water wash, providing they can be transferred directly to the chromium bath.

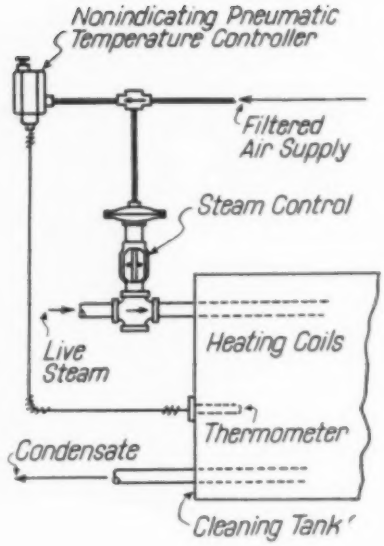


Fig. 1 — Diagram of Temperature Control System for Cleaning Tank

Control of Cleaning Baths — Temperature control of hot alkaline cleaning baths is necessary to insure operation at maximum efficiency without waste of fuel. A recommended system for the cleaning baths comprises a remote bulb, air operated, nonindicating temperature controller (with a range of 100 to 220° F.); a steel well for the bulb; and a low-lift, V-ported diaphragm, steam valve with bronze body and trim. (See Fig. 1.)

Location of the thermometer bulb is a primary consideration. It should be placed where a representative temperature exists, sufficiently remote from the source of heat. In an electrolytic cleaning tank the bulb must be away from the path of current flow, else the well will be rapidly corroded. Usually the best location is at the end of the tank rather than at the side.

This system is low in cost; because of the economies which will accrue from its use, it will rapidly justify its installation.

Chromium Plating Process — Bright chromium plate is the result of optimum operating conditions, including both bath temperature and cathode current density, factors which not only are affected by each other, but by a number of other variables, such as bath composition and concentration and the structure and material of the electrodes. Chromium baths are extremely sensitive to any change in these variables and thus require highly accurate control.

Chromium deposits may be divided into four appearance classifications which are indicative of the nature of the deposit — milky, bright, frosty and burnt. With any given controlled set of variables, milky deposits result from high temperature and low current density, while frosty or burnt deposits result from high current and low temperature. Milky deposits sometimes may be corrected by increasing the thickness of the plate. Frosty deposits can be corrected only by buffing — usually impractical because of the hardness.

Generally, to deposit bright chromium, an average current density (lying halfway between the points at which milky or frosty deposits are obtained) should be employed. The average density varies widely, depending upon the plating bath used. The plating range for various metals in a bath of known composition (2.5 molar in CrO_3 and 0.05 normal in SO_4) is illustrated in Fig. 2.

It will be found that cathode efficiencies for producing bright deposits are nearly equal regard-

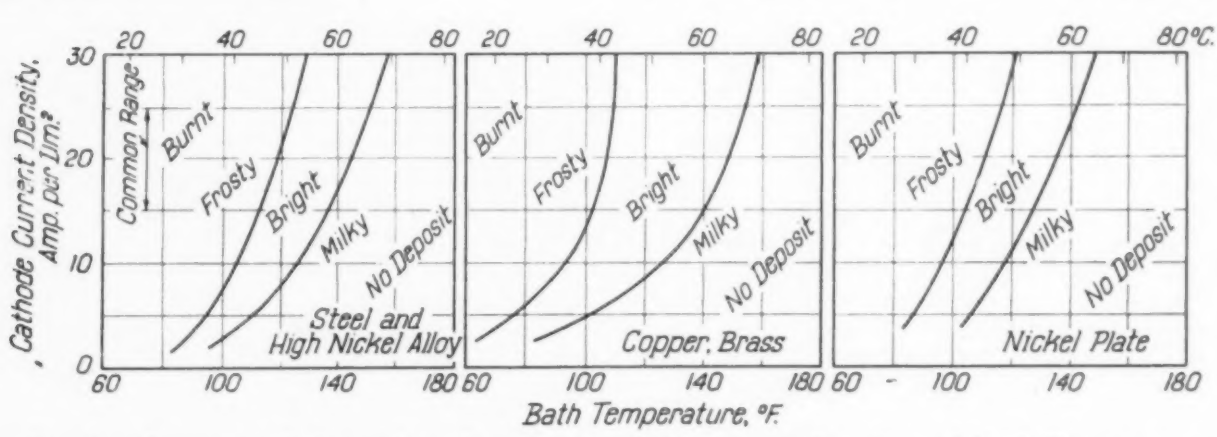


Fig. 2 — Operating Relationships Between Cathode Current Density and Bath Temperature for Various Types of Chromium Deposits. Bath contains 2.5M CrO_3 and 0.05N SO_4

less of whether the current density and temperature are high or low. Consequently, it is desirable to use the highest possible current density and temperature consistent with satisfactory plating in order that the tanks may handle material at the maximum rate. Current densities for chromium plating are usually much higher than in general plating practice and, as shown in Fig. 2, vary with the metal the object is made of — even when all other variables are maintained constant.

Current densities between 16 and 25 amp. per sq.dm. are common. Fortunately, chromium plating baths have low electrical resistivity. Notwithstanding this characteristic it is frequently necessary to use a 10-volt electromotive force.

The constituents of chromium plating baths are strongly oxidizing materials and hence highly corrosive. Ample protection must be provided for

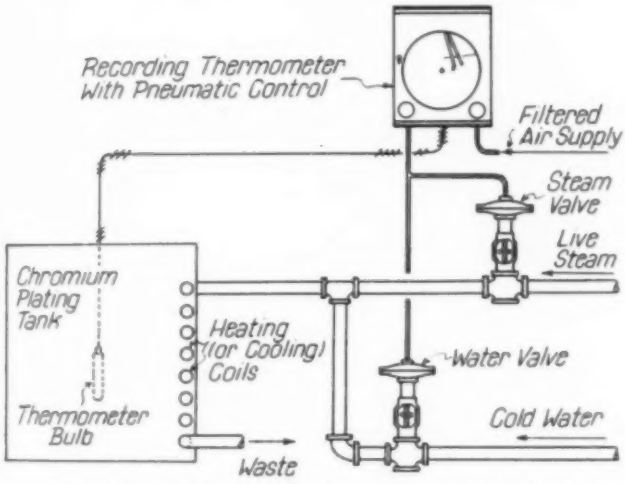


Fig. 3 — Diagram of Temperature Control System for Chromium Plating Tank

the tanks and all other equipment. Since it has been found that lead becomes passive in the bath, hard lead (6% Sb) is frequently used for lining the tank and covering the fixtures.

The throwing power (or ability to plate in recesses) of chromium plating solutions is notoriously poor. As far as is known the only method for plating irregular articles consists of carefully racking the work and suitably arranging anodes which roughly conform to the surface to be plated. Minor improvements in throwing power can also be obtained by reverse electrolysis (with the work as the anode) for a minute or two previous to plating. Reverse electrolysis has an additional merit in that it further cleans the surface.

Control of Chromium Plating — While there are many variables which must be controlled to produce bright chromium plate, most of them must be determined and fixed either before starting the process or at infrequent intervals during operation. The two conditions which *must* be constantly watched during operation are current density and temperature else all previous efforts toward quality deposits are rendered valueless.

If temperature is maintained at a constant level no difficulty is experienced with current density. All that is required is an occasional check on the voltmeter and the solution concentration. However, it is imperative that temperature be maintained constant or the current density will change. It is apparent the most critical variable is the bath temperature.

Because it is essential to the process, and is so easy to secure, temperature control should be considered an absolute necessity.

Details of Control System — The components of a control system for a chromium plating tank include a proportioning pneumatic thermometer controller (reverse acting, 10% throttling range) with a mercury filled, antimony-lead covered, thermal system, and two split-spring type, diaphragm motor, control valves. The preferred range of the thermometer is 50 to 200° F. The system is illustrated in Fig. 3.

One of the two valves is for steam service and is set to be fully closed at about 7½ lb. air pressure and fully open at 14 lb. The other valve is for cooling water control and is adjusted to be fully open at 1 lb. and fully closed at about 7 lb.

The thermometer indicates and records the temperature of the bath. It automatically operates steam and cooling water valves to maintain a constant temperature. When the bath temperature is below the manually adjusted set point of the instrument, steam is admitted to the coils; when the temperature is above this point, cooling water is admitted. Both valves are closed when the temperature is at the desired point. The proportioning action of the controller gradually decreases the steam or water as the temperature approaches the set point and prevents overshooting.

Installation — When the instrument is installed, it should be located where it will not be damaged by corrosive vapor from the plating tank.

Correct placement of the bulb is also highly important. It must be sufficiently remote from the heating coils and the side of the tank to detect a true average bath temperature, but must not be in a position where it is likely to be damaged when work is placed in or removed from the tank. In some installations an open-ended sheath for the bulb will be desirable. If the bulb is between the anodes and the work it will interfere with the process by becoming an intermediary electrode. Usually the best location for the bulb is between the anodes and the tank wall.

A round-up of articles describing interesting variants in polishing methods which give their originators superior results when sectioning metals having difficult or unusual characteristics. Two more lengthy descriptions of mounting methods for soft materials — one for iron powder and one for anodic coatings on aluminum — will follow in next month's issue.

NOTES ON POLISHING TECHNIQUE

POLISHING OF 0.60 CARBON STEELS

By C. PATRICK KENYON
Chief Metallographer
Sheffield Steel Corp., Kansas City, Mo.

WARTIME STEELS, such as W.D. 4150, N.E. 8665, and similar medium- to high-carbon steels proved somewhat of a problem to the metallographer, as it is at times difficult to eliminate all of the disturbed metal to reveal the true structure, even upon repeated etching and polishing. This is especially true of such alloys in the annealed state, and for samples that are to be photographed at 1000 to 2000 diameters.

The procedure that has worked satisfactorily for hand polishing in our laboratory is to take the mounted specimens through the 100-D and 320-A Carborundum grinding papers and then through the lead laps using the customary optical emery powder.

The specimen then is etched for 45 sec. in picral and rough polished on black satin at 600 r.p.m. using the "Linde Polishing Powder — A" in solution. Specimen is again etched and finally polished on either "Gamal" or "Miracloth" at 250 r.p.m., using either "Linde Polishing Powder — B" or Gamal suspension. The specimen is then etched immediately in picral, the time depending

Fully lamellar | Partially spheroidized | Spheroidized

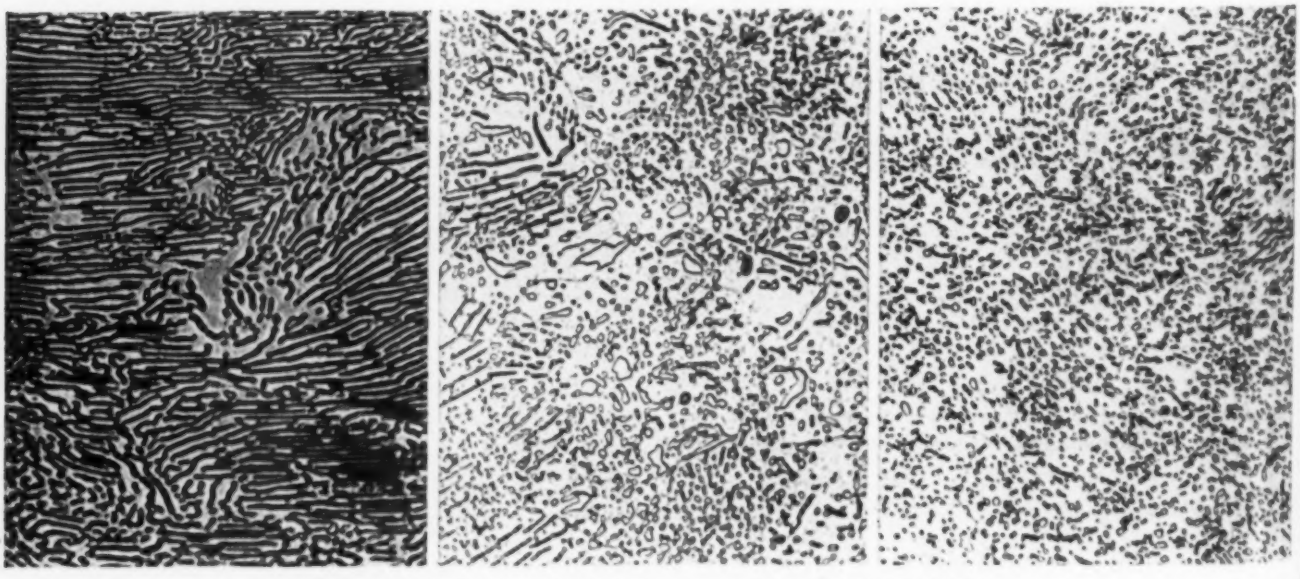


Fig. 1 to 3 — Annealed Structure of N.E. 8665 at 1000 ×

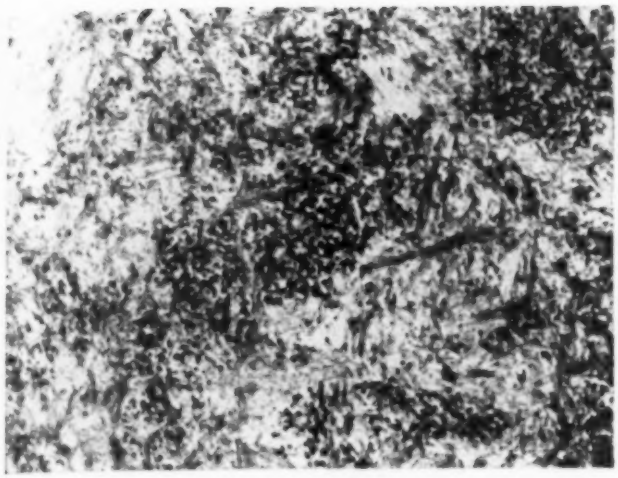


Fig. 4 — Fine Martensite With Undissolved Carbides; 1000 ×

upon the magnification at which the sample is to be photographed.

This procedure has worked quite successfully for us and time consumed for hand polishing each specimen is approximately 15 min.

The polishing powders noted were introduced during the war by Linde Air Products Co. Type "A" powder is of hexagonal α Al_2O_3 with particle size of about 0.3 micron, true density 4.00 g. per cc., hardness 9 on Mohs' scale. Type "B" used for final polish is composed of fragments of cubic crystals with particle size of less than 0.1 micron, true density 3.6 g. per cc., hardness of equivalent material in solid crystal form is 8 on Mohs' scale.

Figures 1 to 3 illustrate at 1000 × the structure of N.E. 8665 in the annealed state — lamellar, partially spheroidized, and almost completely spheroidized.

For alloy steels in the heat treated state we use the same method of polishing but find that adding a small amount of 5% m-nitrobenzene-sulphonic acid to the picral solutions helps to bring out the detail of the structure at high magnification. Figure 4 (at 1000 ×) shows fine martensite with undissolved carbides, and Fig. 5 (at 2000 ×) a martensitic structure infested with microcracks.

Fig. 5 — Martensitic Needles Infested With Cracks; 2000 ×

We have found that the Wratten and Wainwright orthochromatic metallographic plates, while bulky for filing purposes, give better detail than film.

ATTACK METHOD FOR PREPARING TUNGSTEN

By HARRY W. WOODS
Metallographer
Metallurgical Research & Development Section,
Sylvania Electric Products, Inc., Bayside, N. Y.

METALLOGRAPHIC preparation of tungsten specimens, particularly when in the form of fine wire, has always required delicate and tedious techniques. Even with the greatest of care, a metallographer who has not had extensive experience with tungsten will often obtain misleading results — that is, the true microstructures may be camouflaged by some fictitious pseudo-structures. As a result of considerable experimentation the author has developed a new technique for polishing and etching and has been using it in preference to the older method. The saving in time and effort has been great and the resultant microstructures have been more reliable as well as more clearly defined.

Before discussing the preferred method, the older conventional procedure may be outlined briefly as follows: The bakelite or other plastic mount containing a massive tungsten specimen is first roughly ground on a metallographic belt sander using a 100, 180, 240 or 320-grit belt, or some combination of them. This is followed by careful hand polishing on No. 0, 00, 000, and 0000 paper. (When preparing fine wire specimens the large grits are bypassed and first polishing is done on No. 0 emery paper.) Final polishing is done on canvas and silk covered metallographic wheels, driven at high speed and moistened with a suspension of No. 2 grade levigated alumina in distilled water. The polished tungsten surface is then etched in a boiling 3% solution of hydrogen

peroxide in water; the etching time may vary from 5 sec. to 1 min., depending upon the size and past history of the tungsten sample. However, it has been found that repeated wheel polishings and etchings are required to remove distorted metal and to obtain a true structure.

The above procedure will be recognized as conventional in metallographic practice, except that (as has been previously mentioned) extraordinary care and skillful manipulation are required. A majority of these steps have been circumvented in the new method.

The essence of the new technique is that the polishing and most of the etching are done simultaneously. Specifically, the mount is carried through No. 0 emery paper as in conventional procedure, and then taken directly to the final polishing wheel, velvet covered and moistened with a cold suspension of polishing medium *plus* etchant. This suspension is prepared by mixing 10 g. of Linde Grade B polishing powder with the etching solution (3.5 g. potassium ferricyanide, 1 g. sodium hydroxide, and 150 cc. distilled water). The mount is polished on the freshly wetted wheel for approximately 15 sec., rinsed in water, dipped in a beaker of the etchant alone for approximately 5 sec., again rinsed in water, and dried. It is then ready for microscopic examination.

The etchant brings out the grain structure of the specimen to a slight degree during the wheel-polishing. The extra 5-sec. dip in the etchant alone serves to reveal the grain structure to the optimum degree. Figure 1 illustrates the polished longitudinal section of a ductile tungsten wire, 0.007 in. diameter, after wheel polishing; the fibrous grain structure can be seen faintly. Figure 2 represents one end of the same specimen after the final 5-sec. etch; here the fibrous structure is clearly evident. (Magnification of both is 300 ×.) A typical necked-down tensile break is also shown in Fig. 2. Figure 3 depicts an equiaxed grain structure in tungsten rod at 100 diameters.

Figures 1 and 3 both represent specimens prepared by the new polishing and etching method; note the clearly defined, scratch-free structures.*

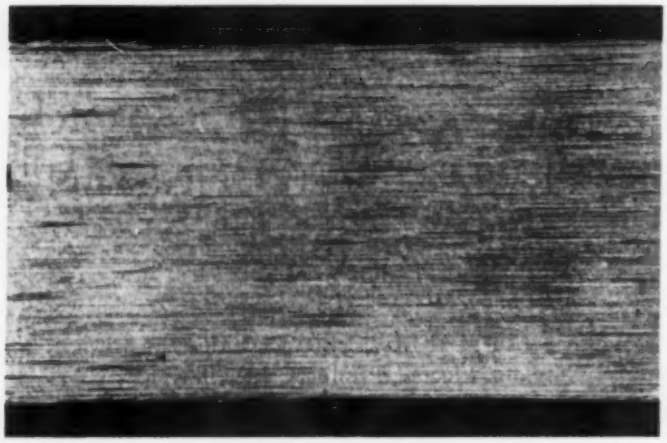


Fig. 1 — Longitudinal Structure of Ductile Tungsten Wire, 0.007 In. Diameter, Photographed After Polishing on Wheel Moistened With Abrasive Suspended in Etchant

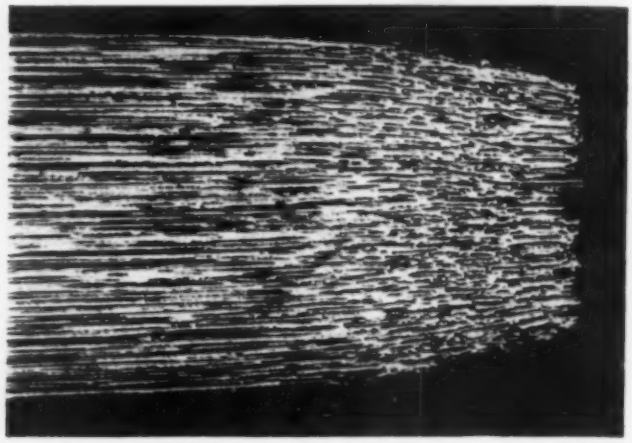


Fig. 2 — Tensile Fracture at End of Same Specimen as Fig. 1 After Fibrous Structure Has Been Emphasized by 5 Sec. in Etchant. 300 ×

In this method of preparation it has been found that greater pressure should be applied to the mount during wheel polishing than in the conventional method. Also it is advisable to mix fresh polishing suspension and etching solution every three days. Otherwise there are no particular precautions that need be taken.

An important achievement of the new method is to minimize the amount of disturbed metal. As has been previously mentioned, the conventional, mechanical method of polishing can often

*The mounting of very fine wires for longitudinal examination deserves brief description. Pieces of the wire about ½ in. long are placed parallel each to each on the base plug of the mold and carefully covered with bakelite powder, which has passed a 100-mesh screen, in a way that does not disturb the original arrangement. The mold is then filled to the proper level with standard bakelite molding powder, and the mount is molded in the conventional manner. Polishing of the mount should only be done in a direction longitudinally with the wires, so as to minimize distortion of the microstructure and to avoid pulling the wires out of the bakelite. A satisfactory technique for mounting fine wires for cross-sectional examination is described by E. S. Norris, metallurgist for Sylvania Electric Products, Inc., under "Bits and Pieces" in the October 1946 issue of *Metal Progress*, page 659.

disguise the true microstructure by distorting or disturbing the crests of metal in such a way that the surface may appear to be perfectly polished, yet will give a poorly defined or even fictitious microstructure on subsequent etching. Repeated polishing and etching will rectify this condition by removing surface layers of disturbed metal to some extent but not completely. Perfectly fibrous tungsten wire may appear to be somewhat recrystallized if the polished surface is badly disturbed.

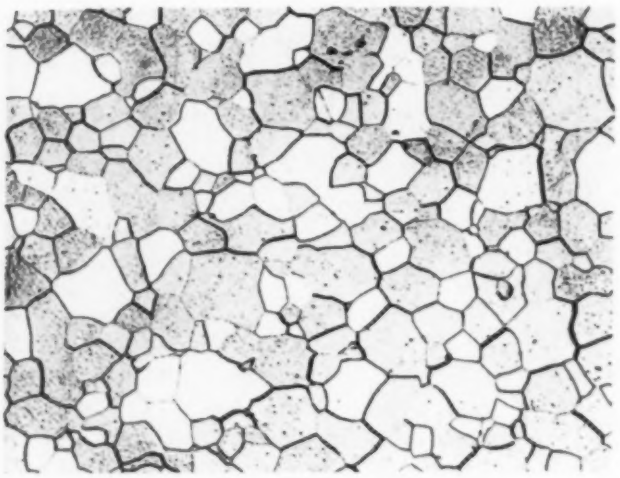


Fig. 3 — Equiaxed Grains in Tungsten Rod. 100 ×

By the new polishing and etching method, however, disturbed metal is practically nonexistent, as has been proved by X-ray diffraction studies.

Advantages of the new metallographic procedure for tungsten over the older conventional technique are reviewed as follows:

1. It is more fool proof. There is less tendency for disturbed metal, and therefore, more accurate and clearer definition of grains and boundaries.
2. There is a considerable saving in time. Specimen preparation (excluding mounting) by the new method takes about 2 min. as compared with 14 min. by the older method.
3. Simplicity. Less skill is required.
4. There is less rounding at the edges.

Before concluding, the use of electrolytic polishing for tungsten should be briefly discussed.

It is true that tungsten metallographic specimens have been prepared very satisfactorily by electrolytic methods in this laboratory. (A detailed description of the process is being prepared.) Such surfaces are superior in quality to those prepared by the conventional, mechanical techniques. However, the main drawback with the electrolytic method lies in the difficulty of making electrical contact on fine wire specimens. For example, 0.0006-in. wire is barely visible to the naked eye; the problem of making electrical contact with such a specimen is obvious. Also if contact could be made, the necessary control of current density would be extremely difficult.

For large tungsten specimens, however, the electrolytic method is entirely practical and compares favorably with the polishing-etching method herein described.

IMPROVED POLISHING CIRCUIT

By JULIUS HOROWITZ and JOSEPH MALTZ
Materials Engineer Metallurgist
U. S. Naval Gun Factory, Washington

IN THE ARTICLE entitled "The Electrolytic Polishing of Brass and Copper" by G. J. Foss, Jr., and Larry Shiller in *Metal Progress* for July 1942, page 77, a simple and fast method for electropolishing copper and copper alloys for metallographic examination was described. It has been the experience of this laboratory, however, since publication of the article, that certain difficulties are associated with the procedure as described. The original apparatus necessitated constant meter observation and rheostat control for maintaining the proper voltage in the cell until the polishing range had been reached and operational stability obtained. Difficulty was experienced in maintaining a stable cell voltage when it was desired to polish within the higher voltage region of the polishing range, thereby limiting the optimum cell potential to 1.1 to 1.3 volts. Sudden fluctuations in cell conditions, excluding line

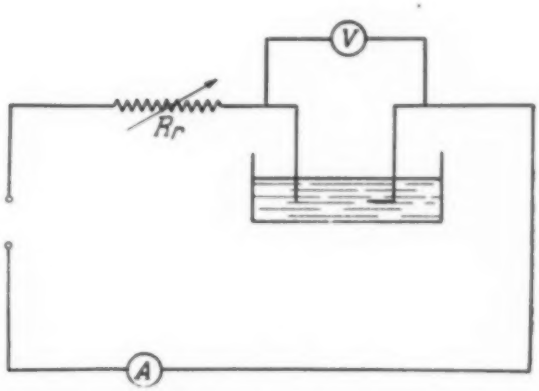


Fig. 1 — Original Electropolishing Circuit Recommended by Foss and Shiller

surges, sometimes caused erratic behavior or excessive voltages which resulted in etching the specimen or gas evolution and specimen pitting.

These difficulties, although relatively minor in nature, were inherent in the original apparatus and were time-consuming when numerous specimens were to be polished. To eliminate them and to stabilize the cell for the entire period of opera-

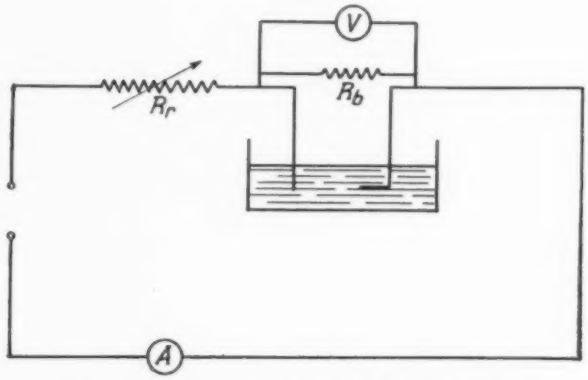


Fig. 2 — Circuit Modified With Secondary Resistance to Stabilize Voltage

tion, a small resistor was shunted across the cell. The original basic circuit is shown in Fig. 1 and the modified circuit in Fig. 2.

The operation of the small resistor R_b is similar to that of the "bleeder" resistors which are often used as simple voltage stabilizers in radio circuits. It is based upon the principle that a parallel combination of a small resistor and a much larger one will have substantially the resistance of the small one alone. In this circuit, R_b has approximately one-tenth the resistance of the cell. The resistance of the combination is therefore independent of cell variations and fluctuations and the voltage across it is maintained at a constant value determined by the values of R_b, R_r and the source voltage.

The advantages of this simple modification may be summarized as follows:

1. It does not require observation after the first minute or so of operation and usually requires no further attention. The rheostats are generally set beforehand, though R_b may be varied during operation if necessary. The same setting is often applicable to any size of specimen and normal changes in bath concentration.

2. Higher polishing voltages may be used with operational stability. The critical nature of the cell between 1.3 and 1.9 volts no longer exists.

3. Polishing time is shortened when using the higher polishing potentials (up to 1.9 volts) and the resulting higher current densities. The desired cell voltage is reached immediately — this also reduces the time of polishing.

4. It simplifies manipulation of the specimen, particularly while it is being taken out of the cell, since the line switch may be left on. The specimen may also be moved about in the bath without affecting the cell voltage.

The modification was also successfully

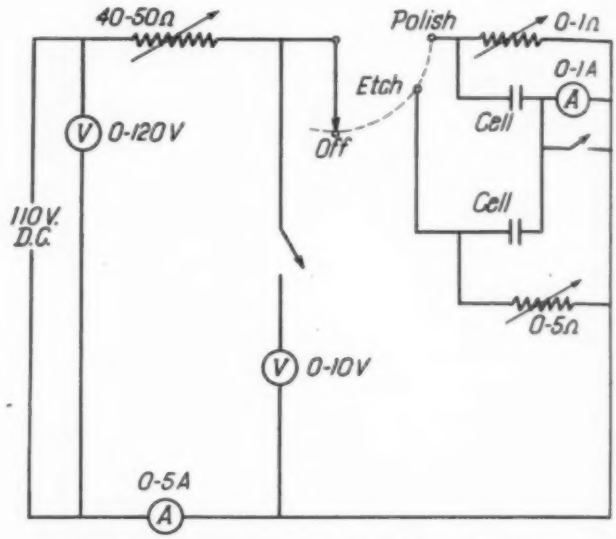


Fig. 3 — Circuits for Combined Electrolytic Polishing and Etching Now in Use in Laboratory at U.S. Naval Gun Factory

employed with the electrolytic etching apparatus referred to in the original article. The circuit diagram for the combination electrolytic polishing and etching apparatus now in use is shown in Fig. 3.

It is probable that the above "bleeder" resistance technique can be successfully adapted to other types of electrolytic polishing apparatus and applications.

CORRESPONDENCE & FOREIGN LETTERS

Is the Hardenability of Boron Steels Indirectly Due to Complete Deoxidation?

PHILADELPHIA, PA.

To the Readers of METAL PROGRESS:

What is presented here is speculative, yet it may lead to an explanation of the unusual effect of boron on the hardenability of steel. As is well known only a very small amount of boron is required to get its full effect. Also this amount is quite critical, and a slight increase beyond this amount will cause the hardenability to fall off. Another characteristic of boron is that it works best when used on steels which have been previously deoxidized.

In order to account for the above, I make several assumptions. The first is that oxygen, as FeO or Fe_2O_3, has a very harmful effect on hardenability when present in very small quantities. (I could find no verification or refutation of this in the available literature.) Next assume that none of the usual deoxidizers are able to remove *all* of the oxygen from molten steel until relatively large amounts of them are in the steel — whereas with boron, only a very small amount in the metal is needed to drive the deoxidation reaction to completion. Thus we have:

$$M + FeO = MO + Fe$$

where M is any deoxidizer. By the law of mass action:

$$(M \times FeO)\ K_m = (MO \times Fe).$$

Since the Fe on the right is very large, the constant K_m must be very large or the M must be made great by excessive additions if deoxidation is to go to completion.

For boron it may be assumed that K_m is much larger than for any other alloying element. This has some basis in fact. One might also go further and say that with boron, the oxidation reaction goes to completion with very small concentration. Thus, boron increases hardenability by the removal of the last traces of oxygen which are retarding it. With other elements K_m is so small that when their concentration is large enough to drive the deoxidation to completion they are present in relatively large proportions. These larger amounts of the alloying elements have such strong effects on the hardenability in themselves that the effect of the removal of oxygen goes unnoticed.

It is also assumed that boron itself is *harmful* to hardenability. Thus, when the amount of boron needed to remove the last traces of oxygen is exceeded, continual additions cause its innate harmful effect on hardenability to emerge.

GERARD H. BOSS
Member ASM

National Metallurgical Laboratory for India

JAMSHEDPUR, INDIA

To the Readers of METAL PROGRESS:

In 1940 the Council of Scientific and Industriai Research of the Government of India was authorized to prepare a plan for establishing a chain of research laboratories, each to serve an industry, and to be appropriately situated. The Metals Committee, late that year, recommended the establishment of a National Metallurgical Research Laboratory, and instituted studies of plans, sites and programs. Interrupted by the war, the final decisions and appropriations have now been made, and the cornerstone of this laboratory was laid on November 21.

The project now in view calls for the construction of a main building to house administration, individual research and routine laboratories, library and other services. It will be a two-story block, 430 ft. long by 90 ft. wide, and arranged for a third floor when funds are available for expansion. Near-by, connected by covered ways, is a high ceilinged area 120 ft. wide by 210 ft. long, in which pilot plant equipment for ore dressing,

smelting and mechanical working will be installed.

Cost of the building and its equipment will be Rs 4,300,000 ($1,150,000 at present exchange), a figure attained only because Tata Iron & Steel Co., the country's leading steelworks, donated a site near its own research laboratories, where existing electrical, water and other supply lines could be tapped with short extensions. Salaries, maintenance and consumable supplies are estimated to amount, at the beginning, to $160,000 per annum.

Work will be undertaken on various aspects of chemical analysis, physical chemistry, physics as it affects metallurgical problems, the examination, preparation and smelting of metallic ores, the melting, heat treatment and working of metals and alloys, research into the structure and physical properties of metals and alloys, the electrodeposition and surface treatment of metals, and research on refractories. Facilities will also be provided for pilot plants for the application of research results to commercial operating conditions and for the study of such conditions as they affect the quality of the products and the efficiency and economy of commercial production. The National Metallurgical Laboratory will work in close collaboration with the other laboratories of the Council, particularly on long term research of a fundamental nature.

The basic staff, at the outset, will consist of a director, 27 research officers, 26 technical or research assistants, 25 mechanics, 18 clerks and 57 nontechnical assistants and laborers.

G. P. CONTRACTOR
Assistant Director
National Metallurgical Laboratory

Cooling Time of Jominy Bars to Half-Temperature

CALDWELL, N. J.

To the Readers of METAL PROGRESS:

Some months ago, B. J. Williams, one of my associates in the metallurgical laboratory of Curtiss-Wright Corp., plotted the time to cool to half-temperature for various distances from the quenched end of ½-in. round by 4-in. long Jominy bars quenched from 1700° F., and produced a curve in the shape of an elongated S. This observation led our former associate, D. J. Blickwede (now assistant in metallurgy at Massachusetts Institute of Technology), to suggest that the points followed the theoretical curve of the modified Gompertz equation,

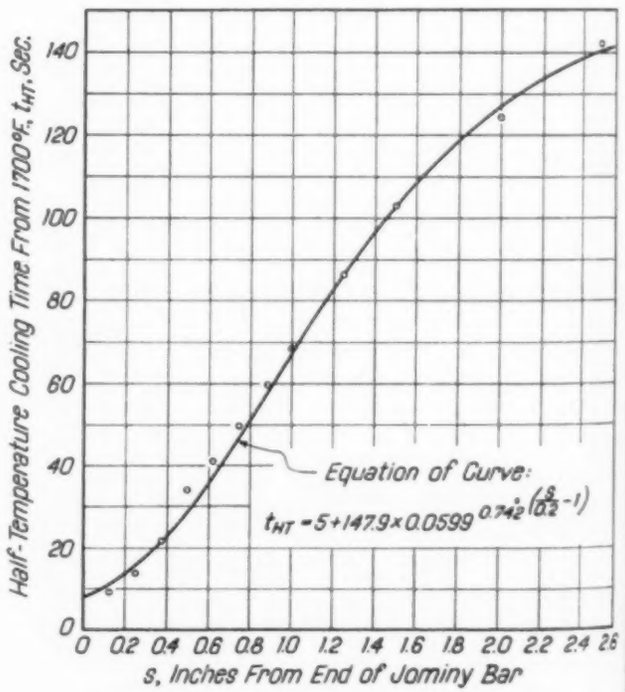
$$y = \alpha + ab^z,$$

where z is itself an exponential form c^x, using the half-temperature time as the dependent variable and the corresponding distance as the independent variable.

Plotting all the data on half-temperature cooling times of Jominy bars developed by this laboratory, an effort was made to fit such an equation to the resulting empirical curve. Half-temperature times were read directly from Speedomax charts. The number of experimental cooling curves for each station on the Jominy bars varied from two to four, except at the ½ and 2½-in. stations, where 22 curves were available. The arithmetic mean of the readings at each station was used to plot the observed data. The standard deviation, σ, for the readings at the ½ and 2½-in. stations was calculated, these being the only two stations for which a sufficient number of cooling curves were available. The value of σ is 2.82 sec. at the ½-in. station, and 16.4 sec. at the 2½-in. station. (It is believed this value was increased greatly by the different cooling characteristics of the types and heats of steel included in our experimental data.)

By methods described in "Empirical Equations and Nomography" by Dale S. Davis, the constants were determined as follows:

$\alpha = 5$
$a = 147.9$
$b = 0.0599$
$c = 0.742$



Observed Values of Half Temperature Cooling Times Along Jominy Bar and Their Relation to a Curve Calculated From a Modified Gompertz Equation

thus leading to the equation shown on the curve reproduced on page 266.

The graph also shows the correlation between observed data and the curve. It is an interesting fit. Whether there is any reason in theory for this fact is unknown to us.

CARL A. LIEDHOLM
Chief Engineering Metallurgist
Curtiss-Wright Corp., Propeller Division

Crystallization!

WASHINGTON, D. C.

To the Readers of METAL PROGRESS:

In an advertisement in *Metal Progress*, page 1163 of December 1946, I read:

"In the breast roller section (above) of the Fourdrinier (paper making) machine, *Beryllium Copper* "shake springs" must hold an oscillating two-ton roller and do it without buckling, corroding, crystallizing, or requiring frequent nursing by the maintenance squad."

The italics are the ad-writers. I restrain my impulse to add a row of ?'s and !'s after the word crystallizing.

L. B. TUCKERMAN
Assistant Chief
Division of Mechanics and Sound
National Bureau of Standards

Crack Sensitivity of Austenitic Weld Metal

YORK, PA.

To the Readers of METAL PROGRESS:

In last September's issue was an article by R. David Thomas, Jr., on "Crack Sensitivity of Chromium-Nickel Stainless Weld Metal", which is a noteworthy exposition of one of the most troublesome and, as he mentions, sometimes inexplicable defects of stainless steel weld metal. We of The McKay Co., through our experience with both lime and titania coated stainless electrodes, agree in principle with Mr. Thomas's remarks. However, we cannot believe that the weld bead illustrated in the left half of his Fig. 1 is a typical product of a titania coated electrode, since its contour is described as "concave".

We have never seen a titania covered electrode which will deposit a concave bead, regardless of manufacturer. The cross sections of weld beads from such electrodes have varied from slightly convex to definitely convex and therefore, in our opinion, the cracking tendency of beads from titania coated electrodes cannot be attributed to the geometry of the cross sections. Convex deposits, typical of titania electrodes, present greater thickness of metal at the centers of the beads, which thickness works to prevent longitudinal cracks in the centers of the beads, like the one illustrated.

It is true that, given a core wire composition which is borderline for bead cracking, the weld metal from that core wire is more likely to show crater or bead cracks when coated with titania than when coated with lime coverings. Many reasons for the difference between the two coatings have been proposed, but none of them have been definitely proven. Both coatings continue to have their proper use in stainless welding.

We have recently made statistical studies of 171 heats of core wire made for us in 1944 and have developed some data concerning the influence of the steel's chemical composition which we believe will be helpful to those interested in this problem of obtaining crack-free stainless welds. The tabular data will be presented for publication in the near future.

RICHARD K. LEE
Metallurgical Engineer
The McKay Co.

Closure by Mr. Thomas

I am wondering if perhaps Mr. Lee's comment regarding Fig. 1 of my paper is not due to a misunderstanding as to the *position* of the welding shown in the illustrations. The welds shown in Fig. 1 were groove welds deposited in the downhand position. Throughout our experience, both with our own and with electrodes of other manufacturers, downhand welds with titania coated electrodes generally produce a flat or concave bead contour, whereas the lime type generally give a slightly convex bead contour. In the vertical or overhead position, however, the reverse is true. I believe, therefore, that this experience should be borne in mind when reading Mr. Lee's statement, "We have never seen a titania covered electrode which will deposit a concave bead, regardless of manufacturer."

Stereographs of Atom Models

NEW YORK CITY

To the Readers of METAL PROGRESS:

All present-day metallurgists are, of course, aware that metallic structures are crystalline aggregates. Not so many of them, however, realize that each "atom" is oscillating constantly in complicated orbits and therefore occupies a space. In that sense it has a *shape*, and is not merely a point in the lattice.

The stereographs on the next page are

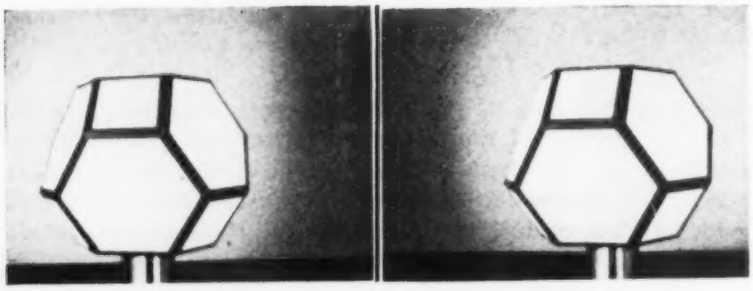


Fig. 1 — The Atom of Sodium, an Example of the Body-Centered Cubic Lattice

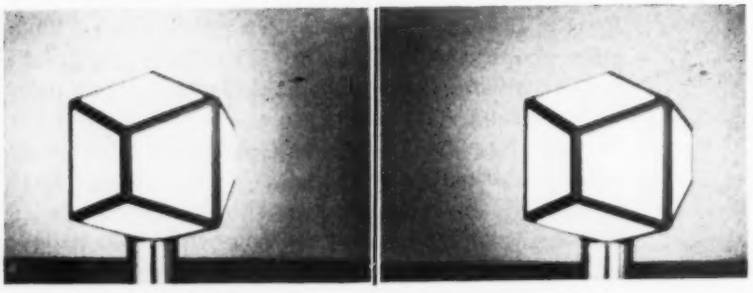


Fig. 2 — The Atom of Magnesium, an Example of the Hexagonal Close-Packed Lattice

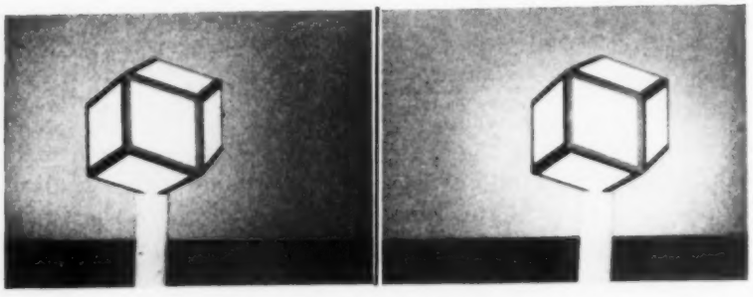


Fig. 3 — The Atom of Aluminum, an Example of the Face-Centered Cubic Lattice

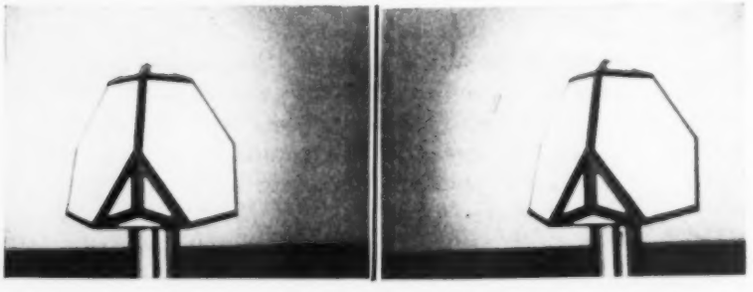


Fig. 4 — Silicon, an Example of the Tetrahedral Lattice

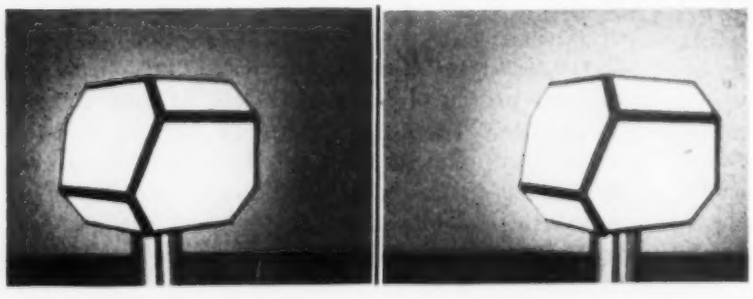


Fig. 5 — Tin, an Example of the Tetragonal Lattice

designed to visualize the geometry of atom sizes far more readily than the usual notation of "face-centered cubic", "hexagonal close-packed", and so on. They may be mounted on cardboard and observed with a stereoscope or, if that is unavailable, by placing a cardboard between nose and center so the right eye sees only the right view and the left eye sees only the left, and then focusing the eyes so the two views move together and merge into a three-dimensional image.

All elements of particular importance to the metallurgist crystallize in five types of lattices. Of these the body-centered cubic and the face-centered cubic are easily visualized, but the other three — the hexagonal close-packed, the tetrahedral, and the tetragonal are far more difficult to grasp.

It becomes much easier to "see" those lattices if we cut the distances between the neighboring points on the space lattice in two by a plane perpendicular to each distance through its center. These planes then form a space figure that might be termed "the individual field of the atom" or, as I prefer to say, the atom itself.

Comparison of Fig. 2 and 3 (magnesium and aluminum, respectively) should indicate the fundamental relationships and differences between these two elements much better than the two characterizations "hexagonal close-packed" and "face-centered cubic".

MICHAEL G. CORSON
Consulting Metallurgist

Identity of Metallurgicus

A correspondent (December issue, page 1211) infers that Metallurgicus is an impostor, or perhaps a mythical person. Metallurgicus has rejoined with a witty three-page "refusal to be drawn into an argument". Perhaps the best way to close the matter is for The Editor to assure readers that Metallurgicus, Cy Anide, Marmaduke Gwynne, D. Carb, Osst I. Temper (and — in this issue — Dr. Izzy Reely Ontowit) are real persons, good metallurgists, each different, and none is The Editor.

Weldability, Ductility and Toughness

HARD KNOX UNIV., RSENALANIA

To the Readers of METAL PROGRESS:

The faculty in the Department of Metallism in Hard Knox University were very interested in Cy Anide's story about the National Metal Congress in the December issue. Prof. Wilnot Arkwright, a recent addition to our department, was intrigued by the fact that Well D. Bility wore a red suit at Atlantic City, because he remarked to me, "Izzy, now I can understand why it is that people so often see red when dealing with Well D. Bility."

That struck me funny too, because I have been confronted by him sometimes in a bright blue suit. These were instances when he was sort of half-way cooperative and not altogether disappointing. And, believe it or not, he sometimes wears a white suit when he is most cooperative and not at all troublesome! Apparently, his disposition is quite changeable and sometimes it is impossible to understand the queer fellow. Certain psychometallists in another department of our university have been hard put to appraise Bility's personality according to present standards. It certainly cannot be done with a single test.

One thing is apparent, however, and that is that he can be good or bad depending on how you handle him. To a certain extent the same may be said of Duck Tility and Tuff Ness. Both are great boys to have on your side in a pinch. But I don't believe Ann Neal would have such a good effect on Tuff Ness although she might be helpful to Duck Tility. You see Tuff Ness is at his best with a temper, although — being temperamental — you can't draw him out sometimes as much as you'd like. But he's not necessarily a hard character.

Some people seem to think that Duck Tility and Tuff Ness are identical twins; that one can substitute for the other at will. To me that is a great fallacy in our metallistic thinking. Of the two I believe Tuff Ness gives a more dependable, all-around performance and he should be given more consideration in any evaluation of the characteristics of Well D. Bility.

The day before yesterday Dr. Arkwright and I were discussing this problem at a seminar in our new Space Laboratory with a group of graduate students in atomic metallism. One bright old boy, Bear Alec Trode, remarked that he couldn't believe that Well D. Bility had anything to do with either Tuff Ness or Duck Tility. He explained that both of the latter are rather ignorant, uncouth, unlettered bruisers whereas Well D. Bility is a Hard Knox alumnus of some social standing so any close connection in cultural circles would be impossible.

Another student, Cuvard E. Lectrode, an American offspring of the old Lectrode family, disagreed with a rather heated argument. I rather sided with Cuvard until Prof. Arkwright was forced to interfere as moderator to end the argument, for the time being, at least. I really don't think he settled the argument entirely because this question is always debatable and often provokes some of the most ridiculous statements imaginable.

In his summation Dr. Arkwright stated that, in spite of his unrecognized cultural standing, Tuff Ness has certain admirably tenacious sticking qualities under extreme, abnormal conditions, and also a code of ethics which makes it quite difficult for people to really appreciate him. (You see people try to avoid abnormal conditions just as much as possible.) "At any rate," I said to myself, "when I visit the Eskimos in Greenland or the Hottentots in Africa, I'll surely try hard to take Tuff Ness along for company."

IZZY REELY ONTOWIT, Ph.D., W.Sc.D.
Professor of Metallism
Hard Knox University

Creep in Hot Valve Springs

TURIN, ITALY

To the Readers of METAL PROGRESS:

Behavior of small helical springs under special applications calls to attention the matter of creep. It is surprising to find that this undesirable property of steel exists at relatively low temperature — say 175° F. Its effect is revealed in the loss of load in needle valve springs in the fuel injector of diesel engines. One phase of this phenomenon has been investigated by us in equipment to be described. Whether the quantitative results (obtained under static loads) would be different if an oscillatory load were superposed is unknown to us.

The equipment used in this study (Fig. 1) is composed of a small platform scale with a very sensitive lever system and a micrometer for reading the set of the spring. The spring and fixtures are enclosed in a furnace at 175° F. Three springs of each steel wire under investigation were tested. The sensitivity of the reading is 0.005 in. (ratio of lever, 5 to 1). It is interesting to note that this device allows us to observe the "set" or change in height of a loaded spring under constant load while in the usual test setup the springs are studied at a predetermined height and variable load.

The micrometer was read from time to time; the tests were prolonged at least for 100 and usually to 300 hr. During the first hour there occurs a part of the set (or deflection), after which the velocity of flow (creep) remains constant for 20 to 50

hr., after which time the rate of change decreases markedly. Average readings on tests of four types of spring wire, after coiling and pretreating in various ways, are given in the table at the right and plotted on log-log coordinates in Fig. 2 (page 271).

These springs were coiled of wire 0.1378 in. dia. Ratio D/d = 2.86. There were 5½ active coils, $1\frac{3}{32}$ in. free length. The loading was 40 kg. (88.2 lb.) and the temperature of test was 175° F. (80° C.). Torsional stress under load was in all tests here reported equal to 55,325 psi., as calculated by Wahl's formula, which gives a summation of torsional and shearing stresses in the wire spring.

Table 1 — Loss of Height of Loaded Diesel Injector Springs at 175° F.

Spring History★	Loss in Height, %		
	After 1 Hr.	After 100 Hr.	After 200 Hr.
1	1.20	2.40	2.45
2	2.24	5.20	5.70
3	1.70	3.40	3.90
4	0.90	3.70	4.00
5	0.08	1.95	2.15
6	0.85	3.00	3.20

★No. 1 — Heat treated 0.96% carbon wire, quenched from 1500° F., tempered at 800° F.

No. 2 — Oil tempered Swedish wire (0.72% C) blued at 465° F. ("Blued" represents a low temperature stress relief.)

No. 3 — Same as No. 2, but blued at 610° F.

No. 4 — Hard drawn wire (1.02% C), blued at 610° F.

No. 5 — Same as No. 3, but spring compressed until all coils touch and held there for 2 hr. at 220° F.

No. 6 — Swedish piano wire (0.92% C), blued at 610° F.

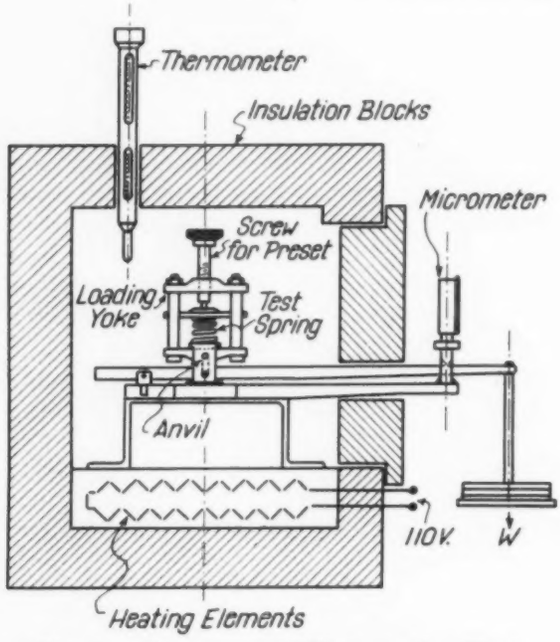


Fig. 1 — Furnace and Fixtures for Testing Helical Springs Under Constant Load and at Moderate Temperature

From the results here presented it seems logical to conclude:

1. That creep is always observed in steel springs tested at 175° F.

2. Springs made from oil tempered Swedish wire blued at 610° F. creep less than if the heat treatment were at only 465° F. (Compare No. 2 and 3.)

3. Spring No. 1 (quenched and tempered 0.96% carbon wire) has the lowest amount of "secondary creep" — that is to say, after the early two stages of rapid change (which can be included in a manufacturing process) the slope of the line representing further change in height is very flat.

4. Spring No. 5 (preset) has the lowest loss of height up to 300 hr., but the rate of secondary creep is much higher than in No. 1, and its loss of height after longer periods under load and temperature would in all probability exceed that of No. 1. In other words, it seems to be in less stable condition.

5. Loss of height of springs No. 3, 4 and 6 after 300 hr. is about the same. Note that all three of these varieties were blued (stress relieved) at 610° F., yet they have quite different microstructure. This, as well as other deductions, suggests that moderate temperature creep in helical steel springs depends more on the residual stress in the wire than on its microstructure.

Alberto Oreffice and Luigi Locati
Respectively Chief Engineer, Steel Dept., and Chief Engineer, Research Dept., The Fiat Co.

Portable Inductor for Heating Metal

Cleveland, Ohio

To the Readers of Metal Progress:

A portable induction heater, first shown as the "Tocco heat gun" at the recent [illegible] convention and exposition, has many interesting possibilities and this communication is to solicit ideas as to possible applications. Induction is so widely used in metal working plants that the underlying principles need not be restated. To the eye, the new tool looks something like a squat riveting hammer. Electrically, it consists chiefly of a multiturn primary coil carrying high frequency alternating current to produce the required heating flux, and a secondary consisting of a split copper sheath to direct this flux against the metallic surface — shoots it out the end of the gun, so to speak.

Connections are made to a conventional 9600 or 10,000-cycle generator through two lines of flexible

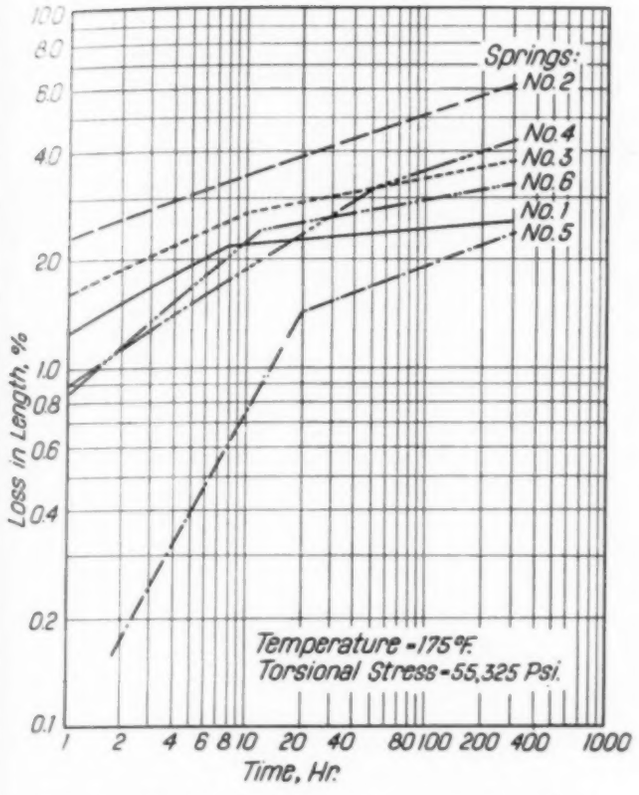


Fig. 2 — Graphs Showing Change in Length of Short Helical Steel Springs at 175° F.

copper braid and two rubber water hoses, arranged concentrically and encased in plastic. These lines can be 20 ft. long or even longer. The cooling water keeps the exterior of the copper sheath below 100° F., and therefore it can be handled with bare hands. Likewise the gun is "cool" electrically — there being no high voltage hazard.

Essentially this device is a portable inductor coil; its obvious functions are similar to those of the brazing torch and the oxy-acetylene flame. The uses which are not so obvious will develop in the hands of users and, as said at the outset, suggestions are welcome.

Since the heat is generated in the workpiece itself rather than in the surrounding atmosphere, it is thought that the portable inductor coil is fundamentally a more rapid heater than a flame of any practicable intensity. The latter must depend on the relatively slow rates of heat transmission from gas to solid. Some heating times measured in Ohio Crankshaft's laboratory are as follows:

Heating for hardening ⅝ in. at the end of a ½-in. round bar: 4 sec.

Heating for upsetting end of ¾-in. pin: 6 sec.

Heating a ⅝-in. round bar for a distance of 1 in. for a sharp bend: 15 sec.

Brazing a carbide tip on a rectangular lathe tool, ¾ in. broad by 1 in. high: 35 sec.

Softening (annealing) the circumference of a pipe 18 in. diameter, ⅜ in. thick: 4 min.

When the "heat gun" is held against a piece of thin sheet steel and the trigger pressed, the currents induced in the sheet take a circular path (approaching zero at the very center) so within one second the sheet has a doughnut-shaped hot spot. A second later, of course, this cool center is hot from heat conducted from the surrounding metal.

J. W. Williamson
Research Engineer, Tocco Division
The Ohio Crankshaft Co.

Metallurgical Substitutions

Paris, France

To the Readers of Metal Progress:

An extended discussion of "Substitute Metallurgical Products" introduced during wartime by French engineers was presented in *Metal Progress* last September, in which a "substitute" was defined as any other metallic alloy which can, *under certain conditions*, be used in place of a more conventional metal or alloy *for a specific application*. For such substitutions the new material should have certain qualities — sufficient values of the ruling properties required in service, such as strength, corrosion resistance — and permissible fabricating characteristics — castability, malleability, machinability.

It is now proposed to present some general considerations applying to any appraisal of alternative materials that underlie decisions in the more normal free economy now approaching.

First of all, it should be mentioned that the specified properties of the part in question may have been actually necessary, but in fact are often in excess of that really required:

1. In excess in *number* of properties when certain of them are not used. For example, parts are frequently manufactured from free-cutting brass simply because of the excellent machinability of this alloy and not because of its corrosion resistance or attractive color.

2. In excess in value or degree, the part having been designed, for other reasons, on an extravagant scale or by pure convention. Thus, many ordinary parts are made of steel when a weaker metal would suffice.

In these two instances, recourse can be had to materials having inferior properties or which even lack certain properties but which still are sufficient for the job. Thus we find that zinc alloys are sufficient for certain parts ordinarily made of brass, or substitute steels are sufficient where alloy steels are usual.

Another consideration results from the *nature* of the properties, classified as follows:

1. *Mass properties* that are dimensional functions — linear (expansion), section (strength), volume (weight, inertia) — for which lower specific values can be permitted provided the dimensions can be increased.

2. *Surface properties* that are functions of the nature and the state of the surface alone, where it is only necessary that the surface possess the requisite properties without the body of the part being considered. Here the body of the part can be manufactured from a different metal from the surface material.

In other words, the whole problem may often be split into two distinct problems, wherein properties under paragraphs 1 and 2 immediately above can be obtained separately, using all known methods of mechanical, thermal, chemical, and surface treatments. This opens up an enormous field of substitution. Specific examples of welding and building-up of surfaces by fusion methods were given in my article printed last fall.

Surface properties may or may not depend on the *area* of the part; if they do — for example, frictional resistance which is dependent upon pressure — the area can often be increased.

Thus whenever surface properties (luster, color, polish, friction, wear) are required in combination with a mass property (strength, electrical properties), the two problems can be studied separately, so as to obtain the strength by using a particular metal treated in a particular way for the body of the part, and the surface properties by using another metal treated in another way. Electrical parts may be constructed of insulating plastic material reinforced with die cast zinc alloys; the zinc gives its mechanical strength and a better dimensional stability to the composite part. This type of design can be extended to many, many machine parts.

Before bringing these general considerations to a close, it ought to be mentioned that, in the search for substitute materials, it is necessary to have a clear insight of fundamental factors that govern properties. These factors were reviewed by the author in *Metal Progress* for April 1940, page 440, in a table that attempted to show the effect of various sized structures or aggregates (atomic, crystalline, mosaic, micrographic) on which the properties depend.

For example, one cannot hope to modify the elastic modulus appreciably — an atomic property — by manipulating mechanical or thermal treatments, whereas such treatment will considerably influence the mechanical strength of a crystalline and micrographic structure. Again, the permeability of metals to X-rays is a function of the atom and can only be modified by working on the atom. To modify the density, it would be necessary to modify the atom or the crystal lattice.

Lastly, a very useful consideration to invoke in comparing the properties of different metals for finding possible substitutes is what may be called the "rule of corresponding temperatures".

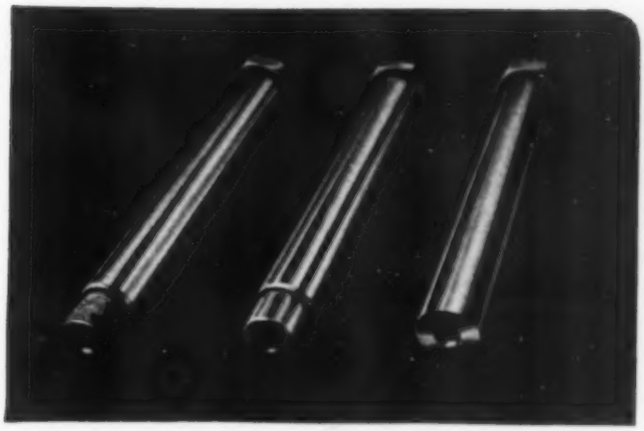
It is the usual practice to compare properties of metals at ordinary temperatures, probably because it is there that the physical and mechanical tests are made, and because atmospheric temperature is of such importance for human life.

Ordinary or room temperatures have no significance for those specialized apparatus operating at elevated or subzero temperatures. Likewise 70° F. has no special significance from the physical point of view — it is just a division on the thermometric scale. Similarly, the fixed points of the usual mercury thermometer (0° and 100° C., or 32° and 212° F.) have been chosen by virtue of the importance of water in terrestial phenomena and human economy, but they have no significance in the study of other materials or elements. This conception, anthropocentric, in that it is based on man as the center of the universe, distorts all the general relations established between the different metals.

On the other hand, if the properties of each substance are compared at a temperature representing the same fraction of the interval between absolute zero and the absolute temperature of fusion, T_f — that is, the "corresponding temperature", or the same value of T/T_f — interesting relationships between the thermal and mechanical properties appear. For example, nearly all metals expand the same amount between absolute zero and the same corresponding temperature, and this gives a ready explanation for the difficulties encountered when substituting aluminum for cast-iron engine pistons. For another example of physical fact related to corresponding temperature, the average temperature of recrystallization of a worked metal occurs, as the present writer pointed out years ago, at $T/T_f = \frac{1}{2}$. In the study of creep it is more logical — according to this concept — to compare the creep rates of zinc at room temperature with those of copper at 635° F. and of iron at 1000° F. When this is done the difficulties arising in certain applications of zinc-base alloys immediately become apparent. Finally in appraising the magnetic properties and certain physical properties of ferromagnetic metals, the Curie point, T_c in degrees absolute, plays the same role ascribed above to the melting point, T_f. Therefore, it is convenient to consider the same value of the ratio T/T_c as the "corresponding temperature".

ALBERT M. PORTEVIN
President, French Society for Metallurgy

Why it pays to bring tube problems to B & W



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By A. L. Boegehold

Martensite in Microstructure at Center	Steel	After Oil Quench (Present S.A.E. Correlation)		After Water Quench			
				Minimum Hardenability According to			
		Minimum Hardenability	Maximum Hardenability	Revised Correlation of Cooling Rates	Present S.A.E. Correlation	Revised Correlation of Cooling Times	Maximum Hardenability
Max. Diameter of Bar That Will Harden at Center to Rockwell C-25							
Less than 20%	4620H	0.40	2.50	0.75	1.00	1.00	3.50
	8620H	0.50	2.70	0.90	1.10	1.10	3.40
	8720H	0.60	3.15	1.00	1.20	1.20	4.00
	8622H	0.75	3.50	1.30	1.40	1.60	4.00+
	8722H	1.00	4.00+	1.55	1.60	1.85	4.00+
	8625H	1.20	4.00+	1.75	1.85	2.15	4.00+
	8725H	1.40	4.00+	2.00	2.10	2.40	4.00+
	8727H	1.60	4.00+	2.20	2.30	2.60	4.00+
	8730H	2.15	4.00+	2.85	2.85	3.20	4.00+
	8732H	2.65	4.00+	3.45	3.40	3.70	4.00+
	8735H	3.15	4.00+	4.00	4.00	4.00+	4.00+
Max. Diameter of Bar That Will Harden at Center to Rockwell C-30							
20%	4620H	0.25	1.25	0.45	0.65	0.65	1.90
20%	8620H	0.35	1.50	0.60	0.80	0.80	2.25
20%	8720H	0.40	1.80	0.75	1.00	1.00	2.50
Less than 20%	8622H	0.40	1.95	0.75	1.00	1.00	2.70
Less than 20%	8722H	0.50	2.35	0.90	1.10	1.10	3.05
Less than 20%	8625H	0.70	2.50	1.15	1.30	1.40	3.25
Less than 20%	8725H	0.75	3.15	1.30	1.40	1.60	4.00
	8627H	1.00	3.15	1.55	1.60	1.85	4.00
	8727H	1.00	4.00	1.55	1.60	1.85	4.00+
	8730H	1.40	4.00+	2.00	2.10	2.40	4.00+
	8732H	1.80	4.00+	2.40	2.50	2.85	4.00+
	8735H	2.05	4.00+	2.75	2.80	3.10	4.00+
	8737H	2.35	4.00+	3.05	3.05	3.40	4.00+
	8740H	2.65	4.00+	3.45	3.40	3.70	4.00+
	8742H	3.25	4.00+	4.10	4.00	4.25	4.00+
Max. Diameter of Bar That Will Harden at Center to Rockwell C-35							
65%	8622H	0.25	1.15	0.45	0.65	0.65	1.85
65%	8722H	0.35	1.40	0.90	1.10	1.15	2.10
50%	8625H	0.40	1.60	0.75	1.00	1.00	2.30
50%	8725H	0.45	2.00	0.75	1.00	1.00	2.70
40%	8627H	0.60	2.00	1.00	1.20	1.20	2.70
40%	8727H	0.60	2.35	1.00	1.20	1.20	3.05
35%	8630H	0.75	2.35	1.30	1.40	1.60	3.05
35%	8730H	0.85	3.00	1.40	1.50	1.75	3.75
25%	8732H	1.20	3.85	1.75	1.85	2.15	4.00+
25%	8735H	1.50	4.00+	2.00	2.20	2.50	4.00+
25%	8737H	1.65	4.00+	2.30	2.35	2.75	4.00+
25%	8740H	1.90	4.00+	2.55	2.60	2.90	4.00+
Less than 20%	8742H	2.35	4.00+	3.05	3.05	3.40	4.00+
Less than 20%	8745H	2.65	4.00+	3.45	3.40	3.70	4.00+
Less than 20%	8747H	3.00	4.00+	3.60	3.80	4.00	4.00+
Less than 20%	8750H	3.40	4.00+	4.00+	4.00+	4.00+	4.00+
Max. Diameter of Bar That Will Harden at Center to Rockwell C-40							
75%	8627H	0.30	1.40	0.60	0.80	0.80	2.10
75%	8727H	0.40	1.60	0.75	1.00	1.00	2.30
70%	4130H	0.50	1.40	0.90	1.10	1.10	2.10
60%	4132H	0.60	2.25	1.00	1.20	1.20	3.00
70%	8630H	0.60	1.60	1.00	1.20	1.20	2.30
70%	8730H	0.60	1.95	1.00	1.20	1.20	2.70
60%	8632H	0.75	1.95	1.30	1.40	1.60	2.70
60%	8732H	0.75	2.45	1.30	1.40	1.60	3.15
50%	8735H	1.00	3.00	1.65	1.60	2.05	3.80
45%	8737H	1.20	3.65	1.75	1.85	2.15	4.00+

(Continued in Table at Right)

Martensite in Microstructure at Center	Steel	After Oil Quench (Present S.A.E. Correlation)		After Water Quench			
				Minimum Hardenability According to			
		Minimum Hardenability	Maximum Hardenability	Revised Correlation of Cooling Rates	Present S.A.E. Correlation	Revised Correlation of Cooling Times	Maximum Hardenability
Max. Diam. of Bar That Will Harden at Center to Rockwell C-40 (Cont.)							
35%	8740H	1.40	4.00+	2.00	2.10	2.40	4.00+
25%	8742H	1.60	4.00+	2.30	2.30	2.75	4.00+
20%	8745H	1.95	4.00+	2.65	2.70	3.05	4.00+
Less than 20%	8747H	2.35	4.00+	3.05	3.05	3.40	4.00+
Less than 20%	8750H	2.65	4.00+	3.45	3.40	3.70	4.00+
Max. Diameter of Bar That Will Harden at Center to Rockwell C-45							
85%	4130H	0.25	1.15	0.45	0.65	0.85	1.85
85%	8730H	0.25	1.40	0.45	0.65	0.65	2.10
85%	4130H	0.30	1.60	0.60	0.80	0.80	2.30
87%	8632H	0.40	1.40	0.75	1.00	1.00	2.10
87%	8732H	0.40	1.60	0.75	1.00	1.00	2.30
87%	8635H	0.60	1.65	1.00	1.20	1.20	2.40
82%	8735H	0.60	1.95	1.00	1.20	1.20	2.70
82%	4135H	0.70	2.60	1.15	1.30	1.40	3.30
80%	8637H	0.75	1.95	1.30	1.40	1.60	2.70
80%	8737H	0.75	2.50	1.30	1.40	1.60	3.25
80%	4137H	0.90	3.85	1.40	1.50	1.75	4.00+
70%	8640H	0.90	2.35	1.40	1.50	1.75	3.05
70%	8740H	1.00	3.00	1.55	1.60	1.85	3.80
60%	8642H	1.00	3.00	1.55	1.60	1.80	3.80
70%	4140H	1.15	4.25	1.75	1.85	2.15	4.00+
60%	8742H	1.20	4.00	1.75	1.85	2.15	4.00+
45%	8645H	1.20	3.50	1.75	1.85	2.15	4.00+
60%	4142H	1.40	4.00+	2.00	2.10	2.40	4.00+
45%	8745H	1.40	4.00+	2.00	2.10	2.40	4.00+
50%	8647H	1.40	4.00+	2.00	2.10	2.40	4.00+
45%	4145H	1.75	4.00+	2.45	2.50	2.85	4.00+
50%	8747H	1.60	4.00+	2.20	2.30	2.60	4.00+
30%	8650H	1.70	4.00+	2.30	2.40	2.75	4.00+
50%	4147H	2.10	4.00+	2.75	2.80	3.15	4.00+
30%	8750H	1.95	4.00+	2.65	2.70	3.05	4.00+
30%	4150H	2.35	4.00+	3.05	3.05	3.40	4.00+
70%	4340H	4.00	4.00+	4.00+	4.00+	4.00+	4.00+
Max. Diameter of Bar That Will Harden at Center to Rockwell C-50							
92%	8637H	0.25	1.40	0.50	0.65	0.70	2.10
92%	4137H	0.25	2.35	0.45	0.70	0.65	3.05
92%	8737H	0.40	1.80	0.75	1.00	1.00	2.50
90%	8640H	0.40	1.70	0.75	1.00	1.00	2.40
90%	8740H	0.40	2.15	0.90	1.00	1.15	2.85
85%	8642H	0.60	2.15	1.00	1.20	1.30	2.85
90%	4140H	0.60	4.00	1.00	1.20	1.30	4.00+
85%	8742H	0.75	2.65	1.25	1.40	1.60	3.40
80%	8645H	0.75	2.50	1.30	1.40	1.60	3.25
85%	4142H	0.80	4.25	1.40	1.40	1.75	4.00+
80%	8745H	1.00	3.40	1.50	1.60	1.90	4.00+
75%	8647H	1.00	3.00	1.50	1.60	1.90	3.80
80%	4145H	1.15	4.25	1.75	1.85	2.15	4.00+
75%	8747H	1.20	4.00+	1.75	1.85	2.15	4.00+
70%	8650H	1.20	3.50	1.75	1.85	2.15	4.00+
75%	4147H	1.40	4.00+	2.00	2.10	2.40	4.00+
70%	8750H	1.40	4.00+	2.10	2.10	2.50	4.00+
70%	4150H	1.75	4.00+	2.40	2.50	2.85	4.00+
90%	4340H	2.85	4.00+	3.65	3.60	3.85	4.00+
Max. Diameter of Bar That Will Harden at Center to Rockwell C-55							
95%	4147H	0.60	4.00+	1.00	1.20	1.30	4.00+
90%	4150H	1.00	4.00+	1.50	1.60	1.90	4.00+

Captain Herres — well known to American metallurgists from his wartime work at Watertown Arsenal — investigated "Japanese Metallurgical Research in Fields Allied to Those of U. S. Ordnance" in the fall months of 1945. His investigation was one of 26 prepared by investigators directed by Col. John W. Cave, chief ordnance officer in Japan after the surrender. What is printed here is an abridgment of his complete report, and gives a good view of the scientific and technical condition in this enemy country during the recent war years, 1940-1945.

SURVEY OF METALLURGICAL RESEARCH IN JAPAN DURING THE WAR

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THE PRINCIPAL metallurgical research projects in Japan during the war were directed toward utilization of low-grade raw materials and the development of substitute alloys to relieve critical shortages, first of nickel, copper, and cobalt, and later of practically all industrial metals. (As a matter of fact, no instance of a substitution which resulted in both technical and economic improvements was found.)

Very little useful work was done at metallurgical laboratories of the Japanese army and navy. Although there were well-organized and well-equipped laboratories and capable research metallurgists in Japan, civilian laboratories were not effectively utilized due to a lack of cooperation and to the technical incompetence of army and navy personnel. Ample funds were provided by three Government agencies which attempted to mobilize and coordinate metallurgical research, but the effort was largely wasted because of the attitude of the military.

A surprising amount of fundamental research was carried on by civilian metallurgists during the war, and systematic analyses of various alloy systems have resulted in the accumulation of a large amount of basic data.

As may be imagined, the language difficulty was the principal obstacle to Americans when they attempted to obtain complete information. A first-class translator does well to convert four pages of Japanese characters into English in a day's time! A few instances of deceit by Japanese personnel were encountered, but a more frequent procedure was for them to play dumb until an appeal was made to their vanity or personal ability. The majority of the most prominent Japanese metallurgists, however, were very cooperative.

Two points of general interest will be surprising to most Americans. The shortages of metals and petroleum products had reduced the Japanese military economy to a level where resistance during the latter stages of the war was entirely suicidal. This may be attributed to a failure to utilize effectively the resources of the conquered territories, to an inability to cope with our attacks on their shipping, and to the devastating effect of fire raids on their industrial cities.

There was an almost universal lack of animosity displayed toward Americans; the attitude of nearly all Japanese was to treat the war losses of industry, home (and even of immediate family) as a joke. Possibly this represented a combination

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of a policy of expediency and an adolescence of character. The latter may also have been evident in the momentary delight shown by sedate Japanese scientists when displaying a magnetic toy or taking a ridé in a jeep.

Do not conclude that Japanese metallurgists are limited in ability and conduct only imitative experimental work. The prestige formerly held by the military may well be enjoyed by their scientists in the future. Their unusual energy and patience in conducting laborious and repetitive experimental work, and their scientific curiosity and ability to use improvised equipment and poor materials, indicate that Japanese scientists may become a more potent force under another economic system.

Organization of Research

Governmental Sponsorship — Metallurgical research was carried out in Japanese army and navy laboratories, university laboratories, special laboratories attached to the universities, independent laboratories, and laboratories of industrial companies, nearly 50 in all.

Three agencies attempted to mobilize and coordinate metallurgical research during the war: The Japan Society for Promotion of Scientific Research, the National Research Council, and the Board of Technology. The first of these was by far the most important in its accomplishments.

The Japan Society for Promotion of Scientific Research is a private foundation organized in 1934. The chairman is Dr. H. Nagaoka, who is 80 years old but very active. He is also president of the Academy of Science, member of the House of Peers, professor of physics at Tokyo Imperial University, and an investigator at the Institute of Physical and Chemical Research. He has traveled widely and speaks excellent English.

He states that the society was under the supervision of the Ministry of Education (which he characterized as the "worst ministry in the world") but that the ministry is represented by "puppets" who have nothing to say. The Army and Navy Ministries were represented by the lieutenant general in charge of the Armament Office and the vice-admiral in charge of the Warship Office. All projects requested by the Army and Navy Ministries were undertaken. The society and its investigators were not informed of the real needs of the army and navy or of parallel investigations in army and navy laboratories — rather, the objectives and applications of requested investigations were camouflaged.

The society had 15 special commissions in all fields of science. No. 10 was for research, production, and fabrication of armor plate; it was formed in 1938 and in 1944 had 54 members representing army, navy, and all important industrial companies and research laboratories. This commission was very influential in determining production policies and methods, but there were no similar commissions for any other ordnance items. In addition to the 15 special commissions the Society for Promotion of Scientific Research had 70 minor commissions of which the following concerned metallurgy: Special (alloy) steel production, pig iron production, corrosion, welding of dissimilar metals, increased production of duralumin, fatigue of metals, and metal bearings. The society also made a large number of grants for researches by individuals.

The National Research Council was an official government agency directly under the Ministry of Education. The chairman was Dr. H. Hayashi, who is 71 years old but fairly active. He is a doctor of medicine and professor of Tokyo Imperial University and, like Prof. Nagaoka, has traveled widely and speaks excellent English. The majority of its research studies on metals were begun in April 1944, at the request of the War and Navy Ministries. 18,700,000 yen was received from the Government for research in all fields. The Army and Navy Ministries promised complete cooperation but, in fact, purpose and applications of research projects were kept secret. None of the metallurgical investigations were completed, and Dr. Hayashi stated that nothing important was accomplished, chiefly because materials and equipment for investigators could not be obtained.

Relations with the Japan Society for Promotion of Scientific Research were said to be excellent. Dr. Hayashi was simultaneously chairman of the National Research Council and chairman of the scientific division of the Society for Promotion of Scientific Research; even so, it appears that there was considerable overlapping of effort. Dr. Hayashi stated that the War and Navy Ministries were represented by incapable persons; while relations with the military were cordial there was no confidence, and there was no liaison with the Board of Technology (the third of the three national agencies).

This Board of Technology was formed in 1942 and was directly responsible to the prime minister. The president, from May 1945 until the end of the war, was Lieut-Gen. R. Tada (retired). He stated that there was little accomplished by his board because of heavy opposition by army and navy personnel until the war situation became very serious.

Projects were submitted by the Army and Navy Ministries to the Investigation Mobilization Council, of which the prime minister was chairman, and Tada, vice-chairman. Approved projects were given

to the board for administration. Neither the board nor the council were informed of the object or the application of research projects requested by the army or navy. Coordination with work of the Society for Promotion of Scientific Research and the National Research Council was through the Ministry of Education.

Of a total of 210 research projects sponsored by the Board of Technology in all fields of science, ten concerned metals and — except for one on development of permanent magnets — all were directed toward the utilization of substitute materials. There seems to have been considerable importance attached to rare metals, a subject in which Tada was personally interested, even against the advice of the prominent Japanese metallurgists.

Thus, it appears that although considerable amounts of money were expended by the three agencies for mobilization of metallurgical research, the effort was largely wasted through definite lack of cooperation by War and Navy Ministry personnel and failure to set up effective liaison channels for application of results of research to the design and production of ordnance *matériel*.

The commissions of the Society for Promotion of Scientific Research (particularly the special commission for armor plate), which had direct contacts with industrial companies, were fairly effective, and it is surprising that such commissions were not set up for many other ordnance items. Funds supplied by the three agencies were used for some worth-while fundamental investigations by a few laboratories, but the large-scale sponsorship of metallurgical research by the Japanese National Research Council and the Board of Technology did not commence until the war situation became serious. The failure to obtain materials for experiment, as well as damage by air raids, prevented progress on many projects. Prof. Ishihara of the Metals Research Institute, speaking of work for government agencies, said that the "money goes into the pocket of the individual professor and very little results are obtained". This may have some basis of fact.

Technical Societies — Paralleling those of other industrial nations are the following technical societies in Japan: *(a)* Iron and Steel Institute of Japan, *(b)* Institute of Metals, *(c)* Casting Institute of Japan, *(d)* Welding Society, and *(e)* Light Metals Association. The first is by far the most important. The second is associated with the Metals Research Institute at Sendai. The Casting Institute and the Welding Society were largely devoted to translation and publication of foreign articles, and were not active during the latter stages of the war.

It does not appear that any of the technical societies participated in, or coordinated, wartime metallurgical research.

Army and Navy Laboratories — The principal metallurgical research by the Japanese army was carried on at the 8th Military Technical Laboratory in Tokyo and at the laboratory of Osaka Arsenal. Limited research on guns and projectiles was done at the 1st Military Technical Laboratory (Tokyo) and on armor and fabrication of armor at the 4th Military Technical Laboratory (Kanagawa).

The 8th Military Technical Laboratory was divided into an administrative section and four sections for fundamental researches on metallic materials, fundamental researches on nonmetallic materials, researches on chemical industrial materials, and researches on agricultural chemical products. The maximum number of employees was 436.

This laboratory was under the direction of a major general of the technical branch of the army; a colonel was in charge of the first section, and majors and captains were in charge of individual projects. The major general was also chairman of the army committees on "Determining Metal Specifications" and "Research on Armor Plate", but the impression was that neither he nor the colonel in charge of the first section were capable technicians and that their duties were largely administrative. Army specifications do not appear to have been significantly influenced by the work of the technical laboratory, and the scope of individual projects was determined by the capabilities of junior officers into whose charge they were given.

The 8th Military Technical Laboratory was an outgrowth of an older army technical center and was moved to its present site in 1942. Facilities of the first section were housed in a large one-story wooden building. A number of testing machines (Charpy impact, tensile, and fatigue), a few small induction melting and heat treating furnaces, metallographic polishing and experimental electroplating equipment, and a low-power heat-electron microscope were installed. Although the area was not damaged by air raids, the equipment was almost completely destroyed either by Japanese attempts to move it out to avoid air raids, or by occupying troops.

The principal subjects of investigation by the first section of the 8th Military Technical Laboratory are as follows:

Steels for armor plate and armor-piercing projectiles (in connection with Osaka Arsenal and 1st Military Technical Laboratory).

Spring steels, particularly for torsion bar springs.

Brittleness of steel at low temperature (discontinued in 1941).

Metal plating to improve corrosion resistance, particularly of screw for army shipping submarine.

Substitute for gilding metal jacket of armor-piercing projectiles.

Phosphoric acid salt coating (stopped in 1943).

Decarburization of steel projectile.

Sintered iron rotating bands.

Iron cartridge case.

Experimental cast iron engine crankshaft (discontinued in 1944).

Utilization of pure iron for vacuum tubes.

Utilization of low-grade aluminum alloys.

Electron microscopic structure of steel.

Dr. Honda, director of the Metals Research Institute, and Dr. Nagaoka, chairman of the Japan Society for Promotion of Scientific Research, both stated the opinion that no useful work was done by the 8th Military Technical Laboratory. Certainly, there were no really outstanding technical or scientific personnel employed there, the work on armor and projectiles was very superficial, and none of the projects were successful.

The laboratory at Osaka Arsenal was under the direction of a colonel of the technical branch of the army. In addition to administrative personnel, it consisted of a section for metallurgical research, a section for chemical and physical control for the arsenal factories, and a section for experiment and production of sabers (established in December 1944, and attained maximum production of one saber per day). A section on welding was discontinued in July 1945.

Kotaro Honda
Director, Metals Research Institute

The metallurgical research section was headed by a lieutenant colonel and included four majors, all technical graduates from Japanese universities; they appeared to be fairly capable. The laboratory and all records were said to have been destroyed by air raids. Most of the work done by the metallurgical research section was directed toward development of substitute materials or improvement in production methods for armor plate, armor-piercing projectiles, gun and liner steels, and rotating bands. The work appears to have been better directed and more effective than that of the 8th Military Technical Laboratory.

Metallurgical research for the Japanese army air force was carried out by the 6th Air Technical Laboratory of the Tachikawa Army Air Arsenal. The organization and results of this work are discussed in Report No. 69 (November 24, 1945) prepared by the Air Technical Intelligence Group, U. S. Far East Air Forces.

The principal metallurgical research by the Japanese navy was carried out by the Naval Technical Research Institute in Tokyo, in close cooperation with the two naval aircraft laboratories — the 1st Technical Research Institute for airplane engines and the 2nd Technical Research Institute for aircraft ordnance, both located at Yosaka. The Naval Technical Research Institute also cooperated with navy yards responsible for the development and manufacture of naval armor and ordnance.

The materials department of the Naval Technical Research Institute was under the direction of a rear admiral with a captain as assistant. Both officers belonged to the technical branch of the Japanese navy and were graduates of the metallurgical department of Tokyo Imperial University. The materials department had a staff of 250, including 44 officers, and was divided into sections for iron and steel, nonferrous metals, nonmetallic materials, and foundry, forging, and machine shops.

The quality of personnel and effectiveness of work appeared to have been considerably higher than for other army and navy laboratories. An effort was made to cooperate with a few university and industrial laboratories, but liaison with the army was nonexistent; parallel investigations were undertaken on many subjects. Metallurgical research projects undertaken by the institute are as follows:

Studies Completed, 1940 to 1945

Armor plate from composite ingot (not applied).

Copper for explosion pressure gages.

Steel cartridge cases.

Zirconium as alloying addition to steel (no application).

High-speed shock testing machine (project suspended).

Fatigue testing of steel and study of notch effects.

Study of copper alloys' resistance to corrosion and season cracking.

Investigation of piano wire for twisted wire springs.

Fundamental study of basic electric furnace steelmelting practice.

Method for obtaining samples for oxygen analysis of steel.

Studies in Progress at End of War

Heat resistant steel for turbines and rockets.

Manufacturing method for magnetostriction alloy (Masumoto's "Alfer").

Study of free-cutting steels (sulphurized and leaded).

Metallic materials for vacuum tubes.

Substitution for nichrome wire.

Sintered iron rotating bands.

Pure iron rotating bands.

Materials for dies for manufacture of iron cartridge cases.

Materials for springs of machine guns.

Properties of steel at low temperatures.

Fundamental study of iron and steel melting.

University Laboratories — The principal laboratories engaged in metallurgical research during the war were at Tokyo Imperial University, Tokyo University of Engineering, Nagoya Imperial University, Kyoto Imperial University, Osaka Imperial University and Kyushu Imperial University.

Students in engineering subjects were generally exempt from military service so that academic work proceeded but, of course, was severely hampered by general conditions. Several universities lost assistant professors and graduate students in the military drafts. This condition, as well as the ability to obtain project assignments and materials for metallurgical research, seemed to have depended almost entirely upon the individual professor's influence and connections in government circles. The organization of the metallurgical departments in the various universities appears to be prewar and the relative standing of the universities was not appreciably affected.

The most important metallurgical researches are believed to be the following:

Work at Tokyo Imperial University (under the direction of Dr. T. Mishima, who invented the M.K. permanent magnet steel (Ni-Al-Co-Fe) in 1931) concerned with substitutes for nichrome, utilization of zirconium as an alloying element in steel, and fundamental studies (gas absorption in metals, plasticity, casting of aluminum alloys, oxidation of steel, transformations in steel, recrystallization, and *Ruckbildung** phenomena).

At Nagoya Imperial University, Prof. Takedo worked on substitute high-temperature alloys and Prof. Sekiguchi on substitutes for 18-8 Cr-Ni welding electrodes for armor plate. Neither of these studies was particularly influential.

At Osaka Imperial University, Prof. Okado (who is also president of the Japan Welding Society) conducted various experiments on the welding of armor plate, but obtained no outstanding results. He also worked on a theory for transformations in steel. Prof. Tagaya developed substitutional corrosion resistant alloys and also a substitute for nichrome.

At Kyoto Imperial University, Prof. Morita made some fundamental studies on the melting and casting of light alloys, and Prof. Nishimura studied the equilibrium diagrams and physical properties of magnesium and aluminum alloys.

Mining, ore dressing, and metal smelting sections of the university laboratories all directed their efforts toward the utilization of low-grade Japanese ores and secondary scrap. These studies are not of general interest outside Japan.

Although commissioned officers of the army's technical branch were sent to several universities as graduate students, they worked on more or less fundamental projects which had no direct importance to the war effort. The ineffectual utilization of university metallurgical laboratories certainly reflects very poor technical direction of metallurgical research by and for the armed forces.

*Intermediate drop in strength after initial hardening of age hardening alloys.

Typical Scene Near Center of the University City of Sendai (December 1945)

Special Laboratories — The Research Institute for Iron, Steel, and Other Metals (Metals Research Institute), attached to Tohoku Imperial University in Sendai, is the most important metallurgical laboratory in Japan. Its international reputation is largely due to the efforts of Dr. K. Honda who has, except for a brief period of retirement, directed its activities since 1915. He invented the K.S. permanent magnets in 1915 and the improved K.S. in 1933, and has written numerous papers on both theoretical and practical metallurgy. For these efforts, Honda has received the Bessemer gold metal of the British Iron and Steel Institute, as well as numerous other honors, and in 1924 was made an honorary member of the American Society for Metals. At 75 years he is still active and has tremendous prestige and influence in Japan.

At the Metals Research Institute, Honda has built an organization which expanded from 86 persons in 1935 to 201 in 1944, and included 17 professors and 16 assistant professors working in the following general fields of metallurgy: Physical metallurgy, steel manufacturing, founding, magnetic sands, low-temperature properties of alloys, magnetics, and light alloys. There does not appear to be any strict departmental division of work and the investigators are given considerable freedom of choice. Although the institute is attached to Tohoku Imperial University, the university does not influence the work nor do the "professors" of the institute have a burden of academic duties.

A list of projects undertaken at the institute in the last few years contains 89 items. The most important war work is believed to be Prof. H. Masumoto's studies of various magnetic alloy systems, which resulted in the invention of "Alfer", an iron-aluminum alloy with good magnetostriction properties. It was widely used for supersonic devices.

Among other studies, the following also appear to be of significance: Dr. Watanabe and Prof. Murakami each studied the ballistic properties of armor plate, and the latter did considerable fundamental work on the effect of alloying elements in armor plate; however, the results of these studies were not applied. Prof. Ishihara studied the corrosion resistance of Mn-Cr-Fe alloys. Theoretical studies of the behavior of metals at low temperatures were made by Prof. Fukuroi and Sutoki; the latter advanced a remarkable theory of low temperature brittleness of steel. Prof. Obinata worked on equilibrium diagrams and properties of light alloys and devised a method of separating the aluminum-silicon eutectic from impure aluminum by centrifuging. Prof. Iwase developed a method of obtaining pure iron from titaniferous iron sand; he also advanced new theories on the mechanism of hardening of steel and the graphitization of cast iron which have excited considerable interest in Japan.

Until the paper shortage limited printing in 1944, the Science Reports of the Tohoku Imperial University regularly appeared,* the majority of the papers with English translations or abstracts. There was said to be no government control of work at Sendai nor censorship of reports. War projects were financed by one of the three government agencies mentioned at the outset of this article. A very poor opinion was held by the professors of the institute for military technicians, particularly of the Japanese army, because of the secrecy of object and applications of war projects, as well as failure to supply necessary data and materials. An exception may have been Masumoto's work on magnetostriction which was closely followed by personnel of the Naval Technical Research Institute.

Relationships between the institute and industrial companies were not close, and Dr. Honda deplores the tendency of these companies toward secrecy. Apparently this condition is gradually improving in Japan.

About 50% of the Metals Research Institute was destroyed in the single air raid of July 9, 1945, which devastated Sendai. Wooden buildings housing melting furnaces, heat treating equipment, powder metallurgy laboratory, foundry, and machine shops were burned. Three modern concrete buildings remain, but work has been at a standstill since the fire.

The Aeronautical Research Institute, attached to Tokyo Imperial University, has a metallurgical section which studied the following subjects: Effect of low temperature annealing on cold worked aluminum alloys, copper alloys, and special steels; properties of aluminum alloys; resistance welding of light alloys; corrosion resistance of magnesium alloys; sintering of pure iron; electromagnetic properties of thin metallic films; and investigations of metallic structures with an ultra-electron microscope. The quality of this work appeared very high. Reports were published (with English translations or abstracts) through May 1944. The institute was undamaged by air raids and has obtained permission for peacetime research.

The laboratory of the Castings Institute of Japan, attached to Waseda University, is under the direction of Dr. T. Ishikawa (retired rear admiral of the Japanese navy's technical branch), who is also president of the Casting Institute of

*(Copies of the war volumes of this publication, as well as many other documents mentioned in this article, are in the possession of Washington Documents Center.)

Japan. Research was conducted on the cause of blowholes in castings, on a permanent (firebrick) mold for light metal castings, and on flow conditions in metal molds. The institute lost nearly all of its personnel in military drafts and none of the researches were successful. Its main effort was to provide consulting service for small foundries.

The Physical and Chemical Research Institute, an independent organization patterned after Mellon Institute, has 33 separate laboratories, four of which engaged in metals research as follows:

Honda Laboratory — Magnetic materials and *Ruckbildung* phenomena in light alloys.

Mashima Laboratory — Study of impact behavior of lead bullets by instantaneous photographs.

Tsuzi Laboratory — Photoelasticity and stress analyses of metal parts.

Iitaka Laboratory — Studies of corrosion resistance by electron diffraction methods.

These studies do not appear to have contributed anything to the war effort. The study of impact behavior of lead bullets was Dr. Mashima's own idea and the results were not applied. He did not study the mechanism of armor penetration. Both the army and navy requested stress analyses of machine-gun parts at the Tsuzi Laboratory, but Dr. Tsuzi claims that insufficient data were given him to lead to any useful result — he was only given one part for study and not permitted to see the complete mechanism.

It appears that these four special laboratories had the best facilities and personnel in Japan for metallurgical research, and the failure to utilize them effectively indicates incompetence of the technical branches of the armed services.

Industrial Company Laboratories — Twenty-two of the more important industrial companies of Japan conducted metallurgical research in their laboratories. The principal work was directed toward solution of production problems, intensified by the necessity for substitution of poor raw materials. The work of the following is believed representative of the best in Japan.

The Japan Iron and Steel Company, Ltd., which accounts for about 50% of Japanese steel production, has laboratories in Tokyo and in Yawata. The Tokyo laboratory had 44 employees in three divisions with work assignments as follows: 1. Physical and chemical investigations of iron, steel, and refractories (most of the work was farmed out to university professors); 2. Development of electrical applications to iron and steel manufacture, and experimental manufacture of electrical control equipment; 3. Department for publication and dissemination of information, particularly foreign translations.

The Yawata works laboratory had many more personnel: 564 employees in seven departments, five of them with research assignments in metallurgy as follows: 1. Raw materials; the utilization of special ores and recovery of incidental alloy contents, such as copper and chromium; 2. Blast furnace profiles and tuyere design, addition of steam to air blast, refining of pig by air blast between furnace and ladle, and addition of copper slag to the blast furnace charge; 3. Manufacture of blast furnace coke from coke breeze and domestic coal; 4. Quality; improvement of silicon steel for transformer sheet, examination of effect of decreased manganese on the properties of steel, increase of ingot yield, substitute for chromium-tungsten steel roll guides, effect of arsenic in steel and cast iron, effect of size of test specimen on fatigue strength, and creep tests of special steels; 5. Refractories for hot stove, conservation of electric furnace electrodes by protective coatings, and protective facing for ingot molds.

The laboratory of the Japan Steel Tube Co. is directed by Dr. T. Fujiwara, who holds degrees from Purdue and Harvard. Work during the war was largely devoted to control and trouble shooting for the company plants. Two major research projects were a process for reduction of mill scale by hydrogen and a method for smelting titaniferous iron sand to pig iron containing vanadium and titanium. Both processes were ready for production on a pilot scale at the end of the war.

The research laboratory of the Sumitomo Copper Alloy Mfg. Co. conducted basic research on aluminum, magnesium and copper alloys. Considerable data were collected on precipitation hardening, *Ruckbildung*, and work hardening phenomena which were investigated by X-ray diffraction and mechanical tests. Fatigue and corrosion resistance of light alloys were also studied.

It appears that the metallurgical laboratories of the industrial companies of Japan pursued their normal functions during the war, with emphasis being placed on solution of difficulties involved in conservation of critical materials. A few cooperative projects, such as utilization of low-grade Japanese iron alloys containing arsenic, and basic research on aluminum alloys, were undertaken by company laboratories under the sponsorship of the three government agencies.

Foreign Influences — Nearly all of the important Japanese metallurgists read and write English (and often German) but very few speak English. All of the metallurgical laboratories have libraries of the important American and British technical publications and textbooks. The Japanese technical societies also translated many foreign articles and reprinted them in their journals. A number of the Japanese metallurgists have visited

abroad and have been shown through industrial plants and research laboratories in the United States. During the past five years, they have greatly missed this influence and have no knowledge of such important developments as the boron treatment of steel for improving its hardenability (which would have been of considerable advantage to them in saving alloying elements).

A number of capable research metallurgists in Japan are conducting systematic fundamental investigations of various alloy systems and are doing original thinking on new theories. Progress would have been much greater had they been given proper encouragement and adequate materials to work with. It is believed that the Japanese metallurgists may soon be on a par in scientific ability with those of more progressive nations; but at present, they lack technicians with ability to apply the results of scientific researches.

Although all Japanese personnel interviewed were questioned as to extent of technical aid received from Germany during the war, the only two examples reported were the development of sintered iron rotating bands at the 8th Military Technical Laboratory (which was taken directly from reports obtained by the Japanese Military Attaché in Germany) and the development of steel cartridge cases (which was influenced by samples obtained from Germany by the Japanese navy).

Dr. Ishiwara, Assistant Director of Metals Research Institute, With His Space Model of the Iron-Carbon-Manganese System

Utilization of Poor-Grade Ores

A cooperative research program sponsored by the Board of Technology was directed toward the utilization of Japanese home ores (low-grade limonite). Many of these ores, including the Hokkaido deposits, contain 2½ to 4% arsenic. Simple sintering was insufficient to reduce this below 0.75%, and many experiments were performed for double sintering, blending, and combined sintering and sieving of fines after sintering. Double sintering with or without blending with low-arsenic limonites or imported magnetites was adopted. No new methods for removing arsenic were found.

Efforts were also made to determine the effects of arsenic and the maximum allowable percentages in various products. Black stains were found to be produced when tinned sheets containing 0.8% As were pickled. The quality of rails decreased at 0.8% As, and rails with 1.05% failed to pass the standard drop-weight impact test. Drawn wire containing 0.6% arsenic was inferior in repeated bend tests.

The electromagnetic properties of silicon transformer sheet were enhanced at 0.7% As, but ductility decreased. Dr. Masumoto suggested that ferrosilicon might be saved by a partial substitution of arsenic in silicon transformer sheet.

Arsenic generally lowers the impact resistance of alloy steels when present in amounts greater than 0.4%, but Murakami's experiments at the Metals Research Institute were made on normalized specimens, and he noted anomalous improvements for certain alloys — possibly due to variations in microstructure (carbide distribution) not taken into account. The effect of arsenic on strength or hardness was found to be slight. No harmful effects of arsenic on nitriding, carburizing, electroplating, metal spraying, or painting of steel were observed. Corrosion resistance was not harmed and resistance to hydrochloric acid and to oxidation at 1800° F. was somewhat improved. Arsenic in amounts over 0.4% gives serious trouble in rolling, forming, and arc or forge welding, and 0.4% is the practical limit of arsenic for structural steels, according to these Japanese investigators.

Japan has a number of deposits of iron sand (titaniferous magnetites) containing about 15% iron; after magnetic concentration, the analysis may be 40 to 55% Fe, 5 to 30% TiO_2, and 0.4 to 1.0% V_2O_5. Iwase of the Metals Research Institute and Fujiwara of Japan Steel Tube Co. each worked out new methods for its utilization. Iwase's method

is to charge the following proportions to an electric furnace having a magnesia lining: 1500 lb. concentrated iron sand, 120 lb. lime, 40 lb. silica, 40 lb. manganese ore from electrolytic ferromanganese industry, 200 lb. slag from previous refining, and 350 lb. coke. Iron recovery of 70% is claimed; analysis quoted is 0.01% C, 0.01% Mn, 0.03% Si, 0.03% max. P, 0.03% max. S.

Fujiwara's method is to charge the concentrated iron sand mixed with coke, but no flux, to an electric-arc furnace with carbon lining. The smelting temperature is higher than 3100° F. A pig iron containing 3.5 to 4.0% C, 0.3 to 1.0% Ti and less than 0.5% Si and Mn is obtained. The slag contains more than 60% TiO_2; the titanium may be recovered by treatment with sulphuric acid.

Both methods seemingly were successful on an experimental scale.

Production of Pure Iron

In addition to the method for producing pure iron from iron sand, Fujiwara of Japan Steel Tube Co. developed a method for reducing mill scale by hydrogen at the relatively low temperature of 1400° F. Hydrogen gas is blown over the mill scale, heated in a reduction chamber fired by fuel gas. The reaction gas is discharged to a water-cooled condenser where steam is removed and the remaining hydrogen is then recirculated. About 95% reduction is claimed in a 2-hr. period.

The process was being put into pilot operation at the end of the war. The product was intended for use as a catalyst in organic syntheses, for powder and metal products, or for melting in an induction furnace to make high-quality pure iron.

Steelmaking

Although much research on steelmaking equilibria and desulphurization, dephosphorization, and deoxidation was in progress, no new or unusual studies were noted; most of the work was really of an elementary nature.

A method of obtaining samples for oxygen analysis from molten steel was developed at the Naval Technical Research Institute: A small refractory ladle which contained 10 g. of aluminum was covered with a thin steel plate and inserted into the steel bath where the plate melted and the ladle filled with steel. The ladle was removed, its contents poured, and oxygen was determined by analyzing the sample for Al_2O_3, utilizing a centrifuge for the filtering operation. This is our own Herty method, slightly modified.

The Japan Special Steel Co. in 1944 patented an apparatus for gas analyses by vacuum fusion. A graphite-lined crucible is used for fusion; a magnet holds the sample in a side chamber until the air is evacuated from the apparatus. Oxygen in the sample reacts with carbon in the crucible and resulting CO is absorbed in KOH; N_2 and H_2 are collected and determined by volume difference after oxidizing the H_2 (oxygen generated by electrolysis).

The Japan Steel Co. also conducted a fundamental study for determining and eliminating nonmetallic inclusions in molten steel. Sampling was attempted by vacuum apparatus but found inconvenient, and a small ingot chill mold was standardized. Nonmetallics were determined by the hot nitric acid method. Cleaner steels were said to be produced by adding ferromanganese and fluorspar to the ladle at tapping; other conclusions of the study were not notable.

Thermocouples of tungsten against iron were used at Sumitomo and tungsten-molybdenum combinations at Yawata and Kure Steel Works for studying the temperature distribution in baths in openhearth and electric furnaces. A small ladle obtained samples of molten steel for temperature measurement, the reading being obtained within 1 min.; an allowance of 55° F. was made for tem-

Jap Kids Like Jeeps, Too

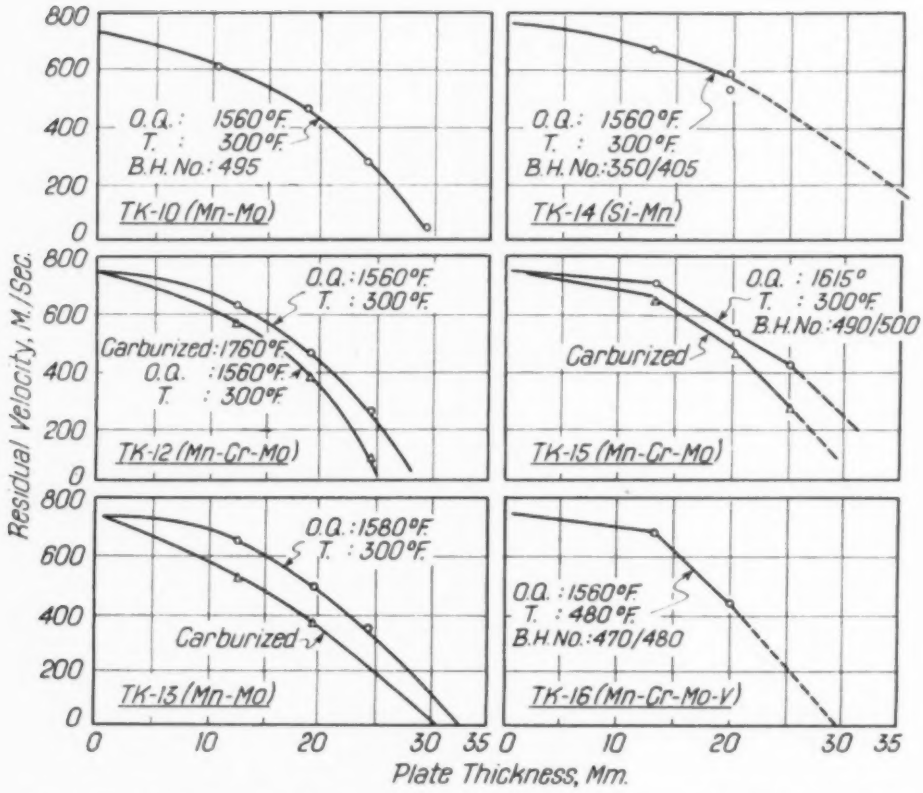

Fig. 1 — Typical Results of Ballistic Tests by Watanabe (Double Pendulum Method). Projectile: 20-mm., steel core, 162 g., 752 m. per sec. OQ = oil quench; T = temper; B.H. No. = Brinell hardness number

	C	Mn	Si	P	S	Cr	Mo	V
TK-10	0.33	2.20	0.19	0.009	0.007	—	0.80	—
TK-12	0.33	2.20	0.19	0.009	0.007	0.99	0.80	—
TK-16	0.35	1.80	0.20	0.027	0.014	0.87	0.35	0.29

perature drop. This procedure was suggested by English metallurgists several years ago.

The Naval Technical Research Institute redesigned the small 110-lb. ingot mold for Alfer (magnetostriction alloy of iron with 13% aluminum) to a squat rectangular shape; this permitted a lower pouring temperature and resulted in less dendritic growth as well as increased yield — but this was not used in production. They also experimented with the process, developed in 1942 at the Muroran works of Japan Steel Co., for obtaining a good surface on steel ingots by pouring a small amount of molten slag into the cast iron ingot mold just before pouring the steel. When casting Alfer ingots, the required amount of high-aluminum slag was removed from the melt and mixed with a small amount of lime, then poured into the ingot mold. This gave a very beautiful ingot surface and negligible peeling — but the scheme never got into production!

No new or important work on casting was reported, and centrifugal casting does not appear to have been considered for important applications.

Structural Steels

The low-alloy high-strength steels were not used to any appreciable extent in Japan, and very little studied. A steel of 0.2% C, 1.0% Mn, 0.7% Si was recommended for structural applications by a committee of the Japan Society for Promotion of Scientific Research, but this was simply a modification of an old steel widely used in Germany, and not the result of new work.

In the heat treatable grades, the nickel-chromium steels were almost universally used in Japan before the war, and the wartime trend was from Ni-Cr to Ni-Cr-Mo to Cr-Mo to Cr-Mn to Cr-Mn-Si. The latter two steels (0.8 to 1.2% Mn, 0.8 to 1.2% Cr with Si at 0.3 to 0.7% and 1.0% Mn, 1.0% Cr, 1.0% Si) were widely used from 1942 until 1944. Toward the end of 1944, even chromium and manganese were short and plain carbon steels were being tested for many critical uses, necessitating redesign to heavier sections.

The Japanese had no successful substitutes for the old high-alloy steels, partly because they failed to balance the hardenability effects of the various constituents, but more because of their failure to improve melting practice. Thus, there is no desire, at present, to utilize the more economical steels in place of the prewar types. They did not have a standard hardenability test or criterion nor adopt any system of metallurgical design based on mass, severity of quench, and alloy content. They did not discover the use of boron — nor even know that we were using it! The important studies on heat treatable steels were for armor plate.

Armor Plate

Theoretical investigations on armor plate were sponsored by a Commission of the Japan Society for Promotion of Scientific Research. This work, directed by Dr. Honda, included an attempt to analyze the breakdown of armor plate during projectile impact, using instantaneous spark photo-

graphs. This work did not pass the elementary stages, and was of no practical value.

At Honda's Metals Research Institute, Watanabe continued work with his double-pendulum method by which the residual velocity of a bullet was measured after passing through test pieces of different thicknesses. A complete description of the apparatus and results of tests with 6.5 caliber projectiles is given in an English translation printed in the Science Reports of Tohoku Imperial University for 1933. During the war, resistance of six steels to 20-mm. armor piercing projectiles was measured by the same method. Results of these tests are given in Fig. 1. The Mn-Cr-Mo (TK-12) and later the Mn-Mo (TK-10) were used as substitutes for the original Ni-Cr steel in the armored vest, invented by Dr. Honda in 1932, and used by Japanese aviators, marines, and police during the war. No other application of these steels or the results of Watanabe's work was reported.

Table I — Selected Results of Murakami's Tests for Nonballistic Evaluation of Armor Plate by Torsion Test

Chemical Composition, %							Heat Treatment*					Quality (Note *a*)
C	Cr	Mn	Mo	W	V	Si	Heat	Hr.		Temper	Hr.	
0.45	1.82		0.59				1615	½	O.Q.	210	1	4.28 mm.
0.41	1.74		0.82				1740 1560	1 ½	A.C. O.Q.	210	1	4.51
0.35	3.19				0.55		1690	½	O.Q.	150	1	4.69
0.59	1.50	1.31	0.76				1690 1615	1 ½	F.C. A.C.	570	1	4.50
0.35		1.29	0.55				1740 1600	½ ½	F.C. O.Q.	300	3	4.62
0.36		1.70	0.52				1580	½	O.Q.	210	3	4.56
0.46		1.87	0.63				1740 1600	½ ½	F.C. O.Q.	300	3	4.25
0.43		1.16			0.23		1615	½	O.Q.	210	3	4.56
0.41		1.61			0.22		1615	½	O.Q.	300	3	4.53
0.40		2.27			0.22		1615	½	O.Q.	—	—	4.44
0.42		0.93		0.97			1650	½	O.Q.	—	—	4.59
0.45		1.73		1.01			1800 1650	1 ½	F.C. O.Q.	400	3	4.57
0.40		1.87		0.91			1650 1650	1 ½	F.C. O.Q.	300	3	4.63
0.34		1.72				0.83	1800 1615	1 ½	F.C. O.Q.	300	3	4.57
0.34		1.51				1.03	1615	½	O.Q.	400	3	4.40
0.42		1.51				1.96	1800	1	F.C.	300	3	4.31
0.48		1.60				0.96	1800 1615	1 ½	F.C. O.Q.	300	3	4.41

*Temperatures in °F.; O.Q. = oil quench; F.C. = furnace cool.

Note *a* — Bullet resistance — thickness in mm. — is the anticipated value from torsion test as taken from calibration curve for firing tests with 6.5-mm. lead core bullet (Watanabe pendulum method). Since this is the thickness of plate required to stop the bullet, the lower the number, the better the armor's quality.

Murakami at the Metals Research Institute did considerable work in developing a nonballistic test for armor plate less than 10 mm. thick. Some results are given in Table I. The quality of the armor plate was judged by a calibration curve in which the energy under the stress-strain curve in a simple torsion test of a 10-mm. round test specimen was plotted against the "bullet-resistance thickness" for a 6.5-mm. lead bullet at standard service velocity, as given by the Watanabe ballistic test. There was a discrepancy in that the resistance thickness of Cr-Mn, Cr-W, and Mn-Si steels was about 1% less for equivalent torsion energy than Ni-Cr and Ni-Cr-Mo steels, and this was taken into account by the calibration chart. The test is, of course, empirical for the given projectile and testing conditions. Again there was no application of the results.

The research and development department of the Japan Steel Works also attempted to develop a nonballistic test for armor plate. The work energy as calculated for penetration of 15-mm. to 40-mm. (0.6 to 1.5-in.) armor plate by 37, 57, and 75-mm. projectiles was compared with the energy to press "statically" a 10-mm. diameter punch, bullet shaped (or a steel ball from Brinell hardness machine) through a test piece 5 mm. (0.197 in.) thick cut from the center of the armor plate. Finally, after making many comparisons and theoretical derivations of doubtful validity, it was concluded that the ballistic quality of the plate was proportional to the maximum load in the static test with the steel ball. Practically, it appears that as much could have been accomplished by measuring the Brinell hardness at the center of the plate, front to back. A large improvement in both the ballistic and nonballistic test results was sometimes obtained by repeated heat treatments of the armor plate — an indication, apparently not recognized, of failure to harden through on the first quench.

Murakami at the Metals Research Institute did considerable work on the effects of alloying elements and conditions of carburizing on depth and structure of carburized case for armor plate. His data were lost in the fire, but the work was on small samples and was reported to be of a fundamental nature — that is, the study of the type of carbides, grain size, abnormality, and carburized depth.

Mishima at Tokyo Imperial University spent considerable effort on zirconium as an alloying element for armor plate. He could not obtain pure ferrozirconium nor adequate armor plate for experimental melts, and his results were largely inconclusive. The Naval Technical Research Institute concluded that it had no beneficial effects on ballistic quality of thin armor plate and abandoned its studies.

The research and development department of the Japan Steel Works made an extensive study on the effects of phosphorus, sulphur and various alloy additions in nickel-chromium steel armor plate, as indicated by Charpy impact energy at various hardnesses. The most interesting conclusion was that phosphorus in amounts over 0.01% greatly accentuated the low-temperature (400 to 800° F.) tempering embrittlement, and that molybdenum additions, and to a lesser extent tungsten, vanadium and aluminum decreased this deleterious effect of phosphorus.

It was also concluded that sulphur in amounts greater than 0.01% is harmful to the impact of armor steel in all ranges of tempering temperature, and that the effect of additional increases in alloying elements to nickel-chromium steel (0.28% C, 0.40 to 0.50% Mn, 3.0% Ni, 0.75% Cr) was as follows: Carbon, silicon, nickel and chromium caused no increase in impact energy, manganese was definitely harmful, whereas molybdenum and tungsten increased the impact value, but only because of their effects on phosphorus and sulphur. In view of the alloy shortage and poor-grade raw materials in Japan, this study was of academic interest.

The Naval Technical Research Institute experimented with a method of casting a composite ingot of 0.10 and 0.45% carbon for armor plate (nickel-chromium steel). An ingot mold containing approximately 50 lb., divided into two parts, was used. A steel plate was clamped to one half of the mold and the low-carbon steel poured; then the other half of the mold was attached and the high-carbon steel poured into the cavity so formed. The composite ingot was rolled to 10-mm. plate. Firing tests were said to be good but, as no advantage over carburized plate was seen, the project was discontinued.

Tests were also made on flame and induction hardening, but neither process was adopted.

Gun Steels

Gun steels were tested by life-firing tests of standard model gun tubes. Chromium plated tubes are described in another ordnance technical report. While no important researches were uncovered, two interesting laboratory erosion tests were used on an experimental scale and said to give results which were similar in trend to each other and to the results of the standard proof-firing tests. The first, developed at Osaka Arsenal, utilized a test piece 20 mm. long with a rifled hole through the central axis. This was fitted into the breech of a special gun and 7.65-mm. projectiles coated with alumite were fired through the hole. The loss in weight was measured after each 50 rounds and the erosion tendency decided after 150 rounds.

The second test, developed by the 1st Military Technical Laboratory, used a small cylindrical test piece with a 3-mm. hole, fitted into the top of a steel chamber. Gun cotton in amounts of 0.1 to 0.9 g., depending on strength, was electrically ignited in the chamber, and the hot gases emerged through the orifice of the test piece. The loss in weight was measured after ten explosions.

Metal Components of Ammunition

No important research projects on steels for armor-piercing projectiles were reported, experimental work being done on a development scale and tested by firing. The simple heat treatment of short-time heating in a radiant furnace, immersion quench in water or oil, and no temper was regarded as satisfactory. Some experimental work on induction hardening was done at Osaka Arsenal, but not applied in production.

Considerable effort was made to find a substitute material for the gilding metal or nickel plate jackets, because of copper and nickel shortages. An attempt was made by the 8th Military Technical Laboratory to produce a low-carbon iron jacket by decarburizing the surface of 6.5-mm. steel projectiles (heating in pure iron powder at 1475° F.). This was said to be abandoned after firing tests showed a decrease in gun life by 30% when using these projectiles.

Japanese use of sintered iron rotating bands was directly inspired by the Germans. The 8th Military Technical Laboratory received reports from Germany via the Japanese Military Attaché and the process was found to be satisfactory without much further investigation.

The development of steel cartridge cases was also influenced by German developments. Although forced to use steel by lack of copper,

manufacturing difficulties and shortages of sufficiently pure low-carbon iron prevented efficient production. No important research on drawability was reported.

Heat Resistant Steels

Due to a shortage of nickel, the Japanese found it necessary to develop new heat resistant steels. Investigations by the same investigators were sponsored separately by the Japanese navy and army. The results of these investigations, the compositions used, and methods of fabrication of heat resistant steels used for rocket, jet, and gas turbine applications, were surveyed by the U. S. Army Air Force and the Naval Technical Missions.

Typical analyses adopted by the Japan Special Steel Co. for production were: A lower carbon steel containing 0.20 to 0.25% C, 0.8 to 1.5% Si, 13 to 15% Mn, 10 to 12% Cr, 0.5 to 1.0% V, 1.0 to 2.0% W; and a second of the same analysis except that carbon was 0.30 to 0.40% and chromium 11 to 13%. The lower carbon steel was intended for parts to be welded by the atomic hydrogen process, using 18% Cr, 8% Ni, 0.4% Cb electrodes or substitute 16 to 18% Mn, 10 to 12% Cr, 1.8 to 2.2% W electrodes.

The Naval Technical Research Institute reported that the addition of 0.2% nitrogen to another standard analysis (0.18 to 0.22% C, 13% Mn, 15% Cr, 0.2% V, 0.3% Si) raised the creep limit of 28,500 psi. from 1110 to 1200° F. The use of nitrogen was a prewar German development, but no success was achieved until the addition was made by the use of nitrided electrolytic manganese —a discovery that came too late to be applied.

Considerable work was done on substitutes for nichrome wire used for resistance heating elements. Mishima at Tokyo Imperial University investigated the Fe-Al-Cr system, and found that 3% Al, 15% Cr gave sufficient oxidation resistance and that further alloy offered little improvement. These alloys tend toward excessive grain growth which induces brittleness. It was later found in a cooperative study with the Tohoku research institute that the addition of 1.0% tantalum prevents grain growth at temperatures of 1600 to 2000° F., and a patent was obtained for this alloy which was in commercial production.

Tagaya of Osaka Imperial University developed a 25 to 30% Cr, 3 to 5% Al alloy with small contents of titanium, manganese and copper as a substitute for nichrome. He has applied for a patent and claims that the alloy is less brittle than Mishima's. The Naval Technical Research Institute recommended 25% Cr, 5% Al, 70% Fe as a standard substitute for nichrome.

Corrosion Resistant Steels

The shortage of nickel also forced the use of straight chromium ferritic irons or chromium-manganese austenitic steels in place of the superior chromium-nickel stainless steels.

Ishiwara, of the Metals Research Institute, investigated the persistence of austenite and the corrosion resistance of chromium-manganese steels with 0.3% carbon and up to 2% nickel. The loss of weight (mg. per sq.cm. of 20% Mn, 0.3% C steels after 30 days in 3% NaCl solution at normal temperature was approximately as follows:

% Cr:	0	2	4	6	8	10	14	16
Loss:	5.2	4.2	4.0	4.0	3.6	2.6	2.9	2.2

The 18-8 Cr-Ni steel had no appreciable weight loss in 30 days. The addition of 2% Ni did not help the higher chromium steels.

Tagawa at Osaka Imperial University investigated the straight chromium-iron alloys. He reported that 18 to 20% chromium-irons without nickel were generally used as substitutes for 18-8. They have almost as good resistance to strong acids but, of course, inferior mechanical properties. A 30% Cr, 0.1% max. C, 0.5% max. Mn, 1.0% Cu, 0.5% Mo alloy was proposed for special uses such as vessels for manufacturing picric acid explosives, and found to have very good properties in laboratory tests, but it was not used in practice.

Treatment with phosphate coatings (Parkerizing or Ferrba methods) was widely used for protective coatings, but no important improvements or developments were reported. Zinc and tin were substituted for cadmium electroplate toward the end of the war, and chromium plate was used for wear resisting surfaces. It was reported that exhaust pipes for airplanes were made of soft iron treated by aluminum dipping or cementation.

Spring Steels

The 8th Military Technical Laboratory developed a steel for torsion bar suspension of army tractors and light tanks. Of the steels investigated, 0.50% C, 0.50% Mn, 1.2% Si, 1.0% Cr, 0.03% max. P and S was recommended. After tempering at 660° F., this steel met the following requirements: Hardness 400 to 500 Brinell, torsional fatigue limit 57,000 psi., torsional proportional limit 21,350 psi. The torsion bar was 1.38 in. diameter and 4.92 ft. long, and was said to have been successful in experimental applications.

The Naval Technical Research Institute investigated piano wire for twisted wire springs used in machine guns. They recommended the following composition: 0.84% C, 0.20% Si, 0.25% Mn,

0.02% max. P, 0.01% max. S, and 0.015% max. Cu. Patenting temperature was 1740° F. and lead bath temperature 1020° F. Impure raw materials decreased the life of the springs; copper in excess of 0.15% was found to be extremely harmful to fatigue resistance.

Toolsteels

Studies were made on the conservation of cobalt in high speed toolsteels and sintered tungsten carbides. Osawa at the Metals Research Institute developed a new alloy (1.3% C, 3% V, 0.2% B, 10% W, 4% Mo, and 4% Cr) which was said to be equivalent to 15% Co high speed steel, but was very difficult to forge. An 18% W, 0.5% Mo, 1.5% V, 0.8% C steel was made in considerable quantity by the Tohoku Metal Industry Co. It gave no difficulties in manufacture, but was an inferior substitute for the cobalt high speeds.

No substitute for the cobalt binder in sintered carbide tools was found. Pure iron, pure nickel, and 20% Cr, 8% Ni were tried, but all were unsatisfactory; 13 to 20% Mn-Fe alloy, cast and powdered, could be used, but the sintering range was too narrow to be practical.

Free-Cutting Steels

The Naval Technical Research Institute studied the leaded free-cutting steels, which have not been used in Japan. The following composition was recommended: 0.15 to 0.25% C, 0.30 to 0.60% Mn, 0.15 to 0.25% Pb, 0.35% max. Si, 0.05% max. P and S. It was stated that this steel permitted an increase in cutting efficiency of 50% and a saving of 50% in manganese over conventional free-cutting sulphurized steels.

Welding

No important new developments or improvements in welding processes or materials were reported. Metal-arc welding was done with either plain carbon or high-alloy austenitic electrodes, and all attempts to use high-strength ferritic electrodes were unsuccessful. The appearance of production welds in army tanks and in naval construction indicated extremely poor workmanship.

Armor welding began in 1931, when nickel-chromium armor ½ in. thick was welded with plain carbon electrodes obtained from Belgium. By 1934, 18-8 Cr-Ni electrodes were obtained from an American manufacturer and applied to armor welding. Welds with the Belgian electrode were unsatisfactory, but those with the 18-8 were acceptable and this electrode, as well as Japanese copies, was used until 1943. In 1942, welding of plates up to 1 in. was permitted. In 1944, it was necessary to use a substitute 15-15 Cr-Mn electrode which was somewhat inferior to the 18-8, both in operating characteristics and frequency of cracked welds. The electrode coating was not changed from a copy of that on the American 18-8.

Studies by Prof. Sekiguchi at Nogoya Imperial University indicated that weld deposits made with the Cr-Mn electrode were not wholly austenitic, and he advocated an increase in manganese and a decrease in chromium by a few per cent — but the results of his work, based on microscope studies, were not applied. Prof. Ikado at Osaka Imperial University studied the effects of welding heat on the base metal and recommended welding with a very high travel speed. This study was inconclusive and no attempts to evaluate the mechanical properties of welded armor joints are known.

Ballistic tests of welded armor joints were only for penetration resistance; 80% of the velocity specified for the armor plate was acceptable for simple butt welds. A simple groove-weld, "torture" test was used to appraise the weldability of plate less than ⅜ in. thick. (Cracking of the armor plate was cause for rejection.) No similar test for greater thicknesses was applied.

The heaviest armor welded in production was 2 in. thick (on the 15-ton tank produced in 1944). 150 tanks were made, using 0.25% C, 1% Mn, 1.5% Cr, 0.4% Mo armor plate and the Cr-Mn electrode. The only heavier tanks were a 30-ton model and the 35-ton model which had 75-mm. (approx. 3 in.) armor. Only one experimental model of each tank was made of welded mild steel.

Weld joint designs were prescribed by the 4th Military Technical Laboratory. Complete penetration butt joints were used for plate less than ⅝ in. and for 2-in. armor. Right-angle corner joints were fillet welds, but obtuse-angle joints and butt welds of 1-in. plate were mortised with overlap of half the thickness of plate.

Armor plate was cut to size by drilling holes and grinding away metal between with an abrasive wheel. Edge preparation was by shaper and hand grinding. There was no preheating or postheating, but peening was employed extensively on weld runs in plate joints thicker than ⅜ in. Direct current reversed polarity was used exclusively, and automatic welding was not considered. Groove and ballistic test welds were X-rayed, but this was not required of production welds.

No progress or outstanding investigations were reported in any other fields of welding. It is quite apparent that the Japanese were behind other industrial nations in welding techniques, equipment, and materials.

*Magnetic Alloys**

Japanese metallurgists have been particularly interested in magnet steels since 1916, when Honda invented the K.S. permanent magnet steel. In 1931, Mishima, of Tokyo Imperial University, invented the M.K. (Ni-Al-Co-Fe) permanent magnet steel, and in 1933 Honda and Masumoto, at the Metals Research Institute, invented the new K.S. (Co-Ni-Ti-Fe) permanent magnet steel.

During the war, much research was carried out on a number of magnetic materials and a large amount of data was accumulated. The most important development is believed to be Masumoto's discovery of Alfer (11 to 13% Al-Fe), a magnetostriction alloy which was widely used in Japan as a substitute for nickel in supersonic equipment. The change of length for Alfer is 40×10^{-6} at saturation (Fe_3O_4 was also found to be large, 30×10^{-6}), but it was not previously known that the addition of a nonmagnetic metal to iron could have this effect.

No important developments in permanent magnet alloys were made. A Permalloy type of alloy (12% Fe, 78.5% Ni, 3.5% Cu, 3.5% Cr, 2% Mn) with high initial permeability was discovered by Mihara at the Furakawa Chemical and Physical Institute and was commercially produced. The occurrence of superstructures in the iron-rich Fe-Ni-Si alloys over a limited range of compositions was discovered and associated with low magnetostriction. These alloys show a constancy of permeability, after annealing, in a magnetic field which was previously associated only with iron-nickel alloys rich in nickel.

The effects of cold rolling on the magnetic properties of silicon irons of commercial purity were studied by the Japan Iron and Steel Co. and by Prof. Kaya of Tokyo Imperial University, but no applications were made of the results.

Light Alloys

Considerable work on new production methods for aluminum followed shortages of good bauxite ores. The U. S. Army Air Force Technical Intelligence Group reported that none of the processes in production or under development overcame the technical and economic disadvantages of producing aluminum from clays and shales.

After 1943, the content of impurities in aluminum alloys, principally iron and silicon, began to increase from the use of impure aluminum from production processes other than the Bayer process, and because of the necessity for consuming scrap. An effort was therefore made to develop methods for refining aluminum and to compensate for impurities.

The most important refining methods were one using gravity separation and a modified Hoopes electrolytic process. Obinata, at the Metal Research Institute, also devised a method of removing silicon from the Al-Si alloy made from clay by direct reduction with carbon in an electric furnace. The alloy is heated to about 1100° F. to melt the Al-Si eutectic and then centrifuged; the silicon content is reduced from 45 to 13% by this process. Utilization of this idea for other metallurgical separations is planned by Obinata.

The effect of impurities in aluminum was investigated by the Furakawa Physical and Chemical Institute. It was concluded that the harmful effect of iron is due to the formation of $FeAl_3$, and that the compound changes to a harmless Al-Fe-Si compound if sufficient silicon is added in excess of that which forms Mg_2Si. The following formula is proposed to determine the proper addition to improve mechanical properties:

$$\% \text{ Si} = \tfrac{1}{2} (\% \text{ Mg} + \% \text{ Fe}) + 0.2\%$$

From this investigation, the following new alloy called ND was developed and produced as a substitute for 24S: 4 to 4.8% Cu, 0.6 to 1.2% Mg, 0.6 to 1.0% Mn, 0.3 to 1.0% Si, 0.8% max. Fe, 1.0% max. Zn. Several other new low grades of duralumin were also proposed, but not produced.

Sumitomo Copper Alloy Mfg. Co.'s laboratory also investigated the effects of iron in duralumin and reached the conclusion that its injurious effect was due to the tie-up of copper as $Al_3Cu_2Fe_2$. Addition of silicon was believed to release the copper. The Furakawa investigation was based on microscopic studies and the Sumitomo investigation on measurements of lattice constants.

An extensive study of the influence of various elements upon the tempered hardness of high-strength duralumin was carried out at the Aeronautical Research Institute in an attempt to find substitutes for Y alloy which contains nickel. Alloys containing 4% Cu, 1.5% Mg, 0.5% Mn, 1.0 to 1.5% Si, and 4% Cu, 1.5% Mg, 0.5% Mn, 1.0% Si, and 1.0% Ag were found to have the highest hardness at 350 to 500° F. These alloys were not produced; duralumin, which was not entirely satisfactory, was substituted for Y alloy where strength at moderate temperature was needed.

With regard to the aluminum-zinc alloys used by the Japanese for several years (and which have very high strength but poor resistance to corro-

*The whole field of magnetic developments in Japan has been surveyed by five civilian experts, and the results of their study will be found in a report by the U. S. Naval Technical Mission to Japan. R. M. Bozorth of this group supplied much of the information discussed in the following three paragraphs.

sion), Obinata found that reduction of the Zn content of "E.S.D." (8% Zn, 2% Mg, 0.25% Cr, 0.3% max. Fe and Si) to 6% improves rolling and extruding properties with moderate sacrifice in strength. These alloys are clad with pure aluminum or with aluminum alloy for corrosion resistance.

Seto of Tokyo Imperial University, who invented an anodic oxidation (Alumite) process in 1936, was questioned as to improvements in this method of obtaining corrosion resistance, but denied any important changes since 1930. The process was widely used in Japan, however.

Morita at Kyoto Imperial University made fundamental studies of the fluidity of aluminum and its alloys and magnesium and its alloys. The reports were published in English in 1942 and 1943, and they contain a great deal of data on the influence of composition and melting conditions on fluidity.

Magnesium production processes in Japan and Japanese magnesium casting alloys are discussed in Air Technical Intelligence Reports. (See also Donald L. Colwell's article in last month's *Metal Progress.*)

T. Fujiwara (D.Sc., Harvard, 1925), Director of Research, Japan Steel Tube Co., and Family

Asada at the Aeronautical Research Institute studied the effect of aluminum, cadmium, zinc, manganese, and iron on the corrosion resistance of magnesium. The voltages of cells consisting of pure magnesium and alloys with the above components were measured in 3% NaCl solution. The minimum voltage appears at 1% Al, 0.6% Zn, 2% Cd, or 0.4% Mn. The minimum weight loss in 3% NaCl appeared at about 0.5% Al, 6% Zn, 4 to 6% Cd, and more than 0.8% Mn. The most anticorrosive alloy of Cd-Zn-Mn-Mg found was 3% Cd, 1% Zn, 1% Mn, bal. Mg. Chill castings of this alloy had 26,000 to 30,000 psi. tensile strength, 13 to 17% elongation, hardness of 50 Vickers, and 11 ft-lb. Charpy impact value. Hot working temperature was 660 to 750° F., and annealing temperature 575 to 660° F.

Obinata at the Metals Research Institute studied the corrosion resistance of magnesium alloyed with manganese, and one of the following as a third element: Calcium, mercury, arsenic, antimony, bismuth, selenium or tellurium. Calcium, mercury, arsenic or tellurium consistently improved the corrosion resistance. Tellurium was most effective, and selenium was very effective but hard to alloy. Addition of antimony in amounts greater than 1% was very bad. No high-tensile alloys were found in this study. Sawamota at Nagoya Imperial University also noted marked improvement of magnesium with selenium.

Other Nonferrous Alloys

The severe shortages of nickel and copper led to substitution by soft iron and aluminum alloys whenever possible. No important investigations on copper alloys were reported.

Considerable study was made of metals for vacuum tubes. Eventually pure iron, fully deoxidized with aluminum and annealed in hydrogen, was substituted for molybdenum and nickel in anode and getter plates. Zirconium, reduced by calcium, was substituted for tantalum as gas-absorbing metal. Electrolytic nickel, with 0.2% magnesium added to improve emissivity, was substituted for Mond nickel. Except for the last, each of these substitutes was said to be slightly inferior to the original.

Fukori at Metals Research Institute investigated solders for low-temperature applications and recommended a 40-60 Pb-Sn base with additions of 2% antimony and 2% cadmium. This was said to be suitable for liquid air equipment.

Masumoto of the same institute investigated the iron-platinum system, and measured its

thermal coefficients. He had discovered in 1936 that the alloys with between 50 and 52% platinum have a negative mean coefficient of thermal expansion in the range from 30 to 125° F. There are no applications of this characteristic, however. Masumoto also obtained a patent in 1942 for alloys of 52 to 60% cobalt, 8 to 12% chromium, balance iron, which have no change in the temperature coefficient of Young's modulus and would be, therefore, suitable for hairsprings of watches.

Okamura at the Metals Research Institute obtained a patent in 1944 for a 94% Ni, 1% Mn, 5% Si alloy, claimed superior to nickel for the pole of spark plugs.

Tagawa at Osaka Imperial University developed a substitute for Hastelloy, in which molybdenum was increased to 30% and nickel replaced by copper and tungsten in ratio of 1 to 3. This is said to have mechanical properties similar to Hastelloy and better resistance to corrosion by HCl. He also developed a dental alloy with the composition of 0.1% C, 70% min. Ni, 8% min. Cr, 5% max. Cu, 10% max. Fe, which was said to be superior to other substitutes for gold.

Fundamental Investigations

A great deal of wartime work by Japanese metallurgists has been devoted to the accumulation of basic data, and to speculations on various metallurgical phenomena which have no direct association with war researches. Most of this was of purely academic interest, and a good part of it consisted of obviously unreliable data and theories with little experimental basis.

The best work uncovered was at the Metals Research Institute, the Aeronautical Research Institute, the Physical and Chemical Research Institute, and at Tokyo, Osaka, and Kyoto Imperial Universities, all of which publish English abstracts or translations so that the important studies will become available in the United States as soon as the Japanese are able to resume publishing and interchange of technical articles. Some of the more important publications have already been forwarded to the Washington Documents Center.

The following theoretical studies carried on during the war, and which were not mentioned in previous sections of this report, are believed to be of general interest:

Iwase and Takeuchi of the Metals Research Institute proposed that martensite is a supersaturated solution of carbon in alpha iron, which forms when gamma iron is supercooled and reaches a temperature corresponding to a prolongation of the "G-P" curve in the iron-carbon equilibrium diagram. They believe that bainite is alpha iron separated from supercooled gamma iron by diffusion at temperatures corresponding to the same prolongation. Since the results obtained by most investigators show that martensite forms at somewhat lower temperatures than indicated by this theory, new determinations were made by the authors and the results agreed with their theory. This theory is in some respects quite similar to that recently proposed by Clarence Zener in the United States, but lacks a logical distinction between the martensite and bainite transformations. The Japanese data on temperatures of martensite reaction may be questioned.

Murakami and Imia, also at the Metals Research Institute, made an extensive investigation of the effects of alloying elements on the isothermal transformation of steel. They investigated steels individually alloyed with manganese, chromium, nickel, silicon, molybdenum, tungsten, vanadium, aluminum, tin, cobalt, and titanium. Six reports have been published and two are in preparation. Magnetic analyses were utilized in some instances to separate the magnetic critical points of carbides, and it was concluded that modifications in the S-curves were due to differences in the type of carbides which separated in the various steels at different temperatures. The principal value of this study is the amount of data accumulated which may be checked against other investigations. The only remarkable feature noted was the unusual results obtained throughout the investigation for temperatures of martensite reactions; this may be due to the technique or equipment but was unexplained.

An attempt is being made by Mishima and Mitsuhashi at Tokyo Imperial University to correlate types of fracture between Charpy impact and tensile test bars. Temperature of testing and rate of loading were not varied nor their effects considered. Considerable data have been obtained, but no important conclusions are likely.

These same investigators have studied, photographed, and classified the results of spark tests (using an abrasive grinder) for a large number of steels. The influence of forging and heat treatment has been studied.

Oketani at Tokyo University of Engineering has devised two novel methods of spark testing. He uses powdered metals (hand filings) which are dropped either through a small resistance coil furnace with open bottom or a bunsen burner flame. He is publishing a monograph with hand paintings of sparks obtained for more than 100 ferrous and nonferrous metals.

Hasiguti at Tokyo Imperial University has published papers on the following subjects: Recrystallization of copper-aluminum alloys as a rate process; neutron scattering of cross section of nickel-iron alloys; relation between activation energy of recrystallization and of self-diffusion in metals; diffusion in cold worked metals. He has also calculated thermodynamically the stable size of aggregates in age hardening alloys as a function of temperature in an attempt to explain quantitatively the *Ruckbildung* phenomena (intermediate drop in strength after initial hardening of age hardening alloys). These papers have been turned over to the Washington Documents Center.

Sato of the Physical and Chemical Research Institute has published a recent report with a large accumulation of data on *Ruckbildung* phenomena in various aluminum alloys.

Some very excellent fundamental work on recrystallization and effects of low-temperature annealing and cold work on the physical properties of various copper and aluminum alloys has been done by Shimura, Isida, Kawasaki, and associates at the Aeronautical Research Institute. Isida obtained remarkably high strengths in copper alloy wires by repeated cold working and low-temperature annealing. He has also found that low-temperature annealing of duralumin at 575° F., before heating for quenching, considerably reduced the grain size. This phenomenon was explained as follows: "If the amount of strain is not uniformly distributed, nuclei are formed first in the severely strained regions and absorb the other crystals as they grow. By low-temperature annealing, the difference in the amount of strain is preliminarily reduced to a minimum without forming nuclei so that nuclei may form at a definite temperature and time, increasing the number and decreasing the ultimate size of grains formed at high temperature."

Sutoki at the Metals Research Institute has proposed a theory on the mechanism of cold brittleness in metals. He has made notch-bar impact tests (using various types of notches) and tensile tests at various rates of loading for vacuum annealed iron, commercially pure iron, 0.3% carbon steel, 0.7% carbon steel, zinc, and aluminum at temperatures ranging from 400° F. down to liquid nitrogen temperature. He finds that the temperature of brittle failure varies with the rate of loading as with the temperature of testing—not a new observation—and proposes that, in accordance with the G. I. Taylor dislocation theory, slip cannot occur instantaneously but requires time. The following equation is proposed:

$$t = \frac{L}{\alpha} \cdot \frac{1}{Z} \cdot e^{\frac{A}{KT}}$$

where t = critical time for slip deformation
L = mean free path of dislocation
α = atomic distance in direction of slip
Z = frequency of thermal oscillation of atom
A = potential barrier at the dislocation
K = Boltzmann constant
T = absolute temperature

Values are assumed for these various factors, and a relationship between rate of loading and temperature of testing is obtained which roughly approximates the experimental results. Finally it is concluded that to increase the toughness (decrease the temperature of brittle failure) for a given tensile strength, the density of dislocations must be increased. This may be done as follows: *(a)* Produce fine grain size; *(b)* strain the solvent lattice by adding elements; and *(c)* unstabilize the structure by heat treatment.

An empirical quantitative relation between strain rate and temperature of testing has recently been proposed in the United States by Zener and Hollomon. Sutoki's theory goes a great deal further, but some of his assumptions are open to question.

Metal structures were studied at the 8th Military Technical Laboratory with a heat electron microscope of low magnification (45×), and at the Aeronautical Research Institute with a home-made electron microscope capable of 20,000×. The former is adapted to study of structures of metals at elevated temperatures, but the investigators were inexperienced and achieved nothing. Tani at the Aeronautical Research Institute obtained photographs of thin metal films deposited on collodion, but was not able to develop a replica technique similar to that used in the United States.

Some very fundamental work on "Thermodynamical Research on the Phenomena of Melting and Crystallization" by Yoshida, and a series of papers on "Strength of Metals Under Combined Alternating Stresses" by Nishihara and coworkers, were published at Kyoto Imperial University during 1944 and 1945, with English translations.

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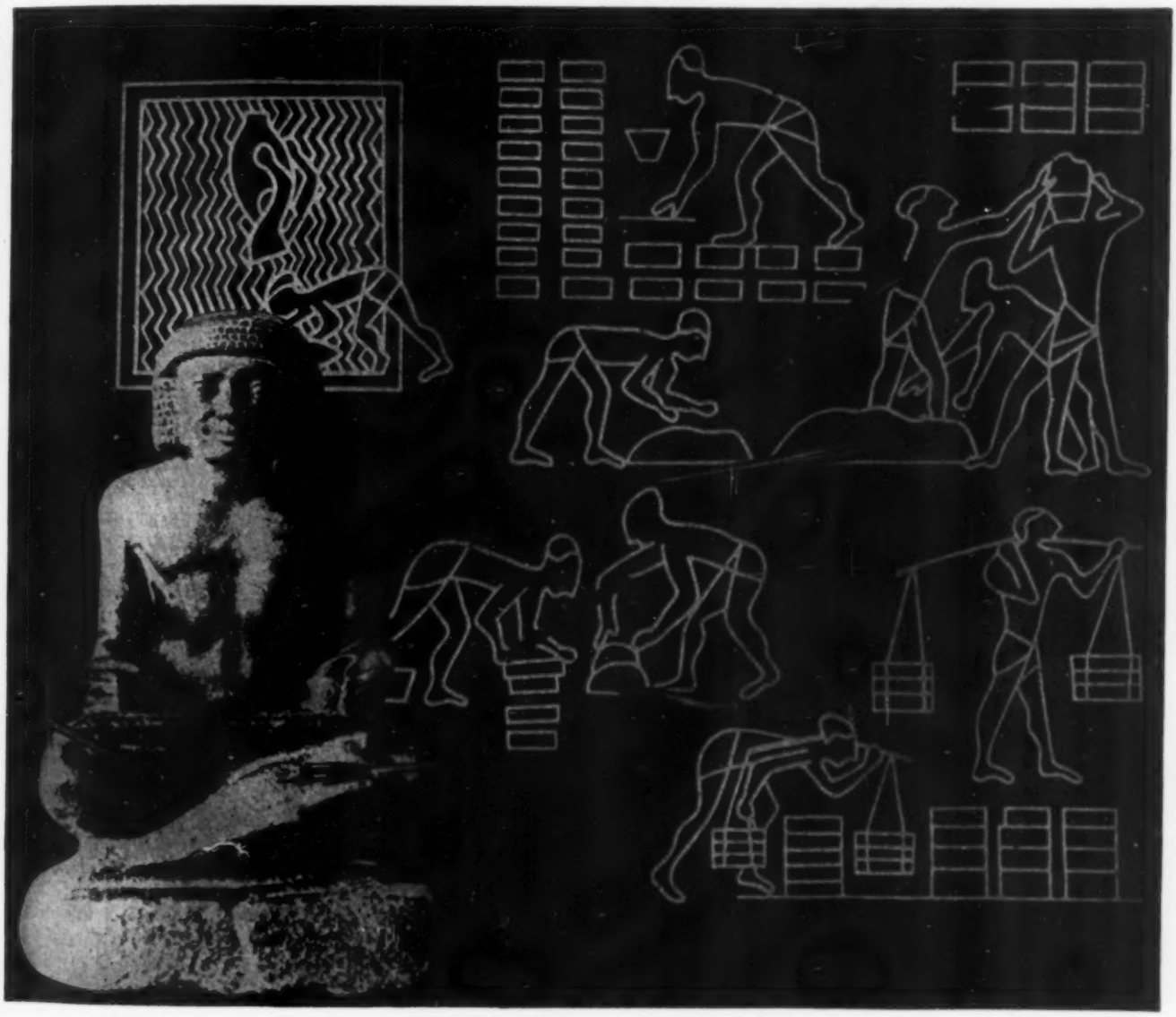

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PERSONALS

R. G. Willaman ⊖, formerly district sales manager of the Copperweld Steel Co., has been appointed sales manager and vice-president of Peterson Steels, Inc., New York.

A. R. Metzger ⊖ has returned to the Bethlehem Steel Co. as a roll designer in the structural division since his release from the U. S. Navy.

Mohammad Anwarul Haque ⊖ is engaging in graduate research work at the University of Utah.

On leave from the Denver and Rio Grande Western Railroad, **R. Wayne Parcel** ⊖ is a metals research fellow doing graduate work at Carnegie Institute of Technology, Pittsburgh.

Willard R. Pratt ⊖ is now chief metallurgist of the Bevil Co., Los Angeles; he is currently in charge of the erection of the new plant of this company.

Max J. Scharf ⊖ has recently been made maintenance engineer in charge of estimates and operations of the Pacific Window Cleaners, Pasadena, Calif.

Alan E. Flanigan ⊖ has joined the staff of the engineering department of the University of California, Los Angeles, as assistant professor in physical metallurgy.

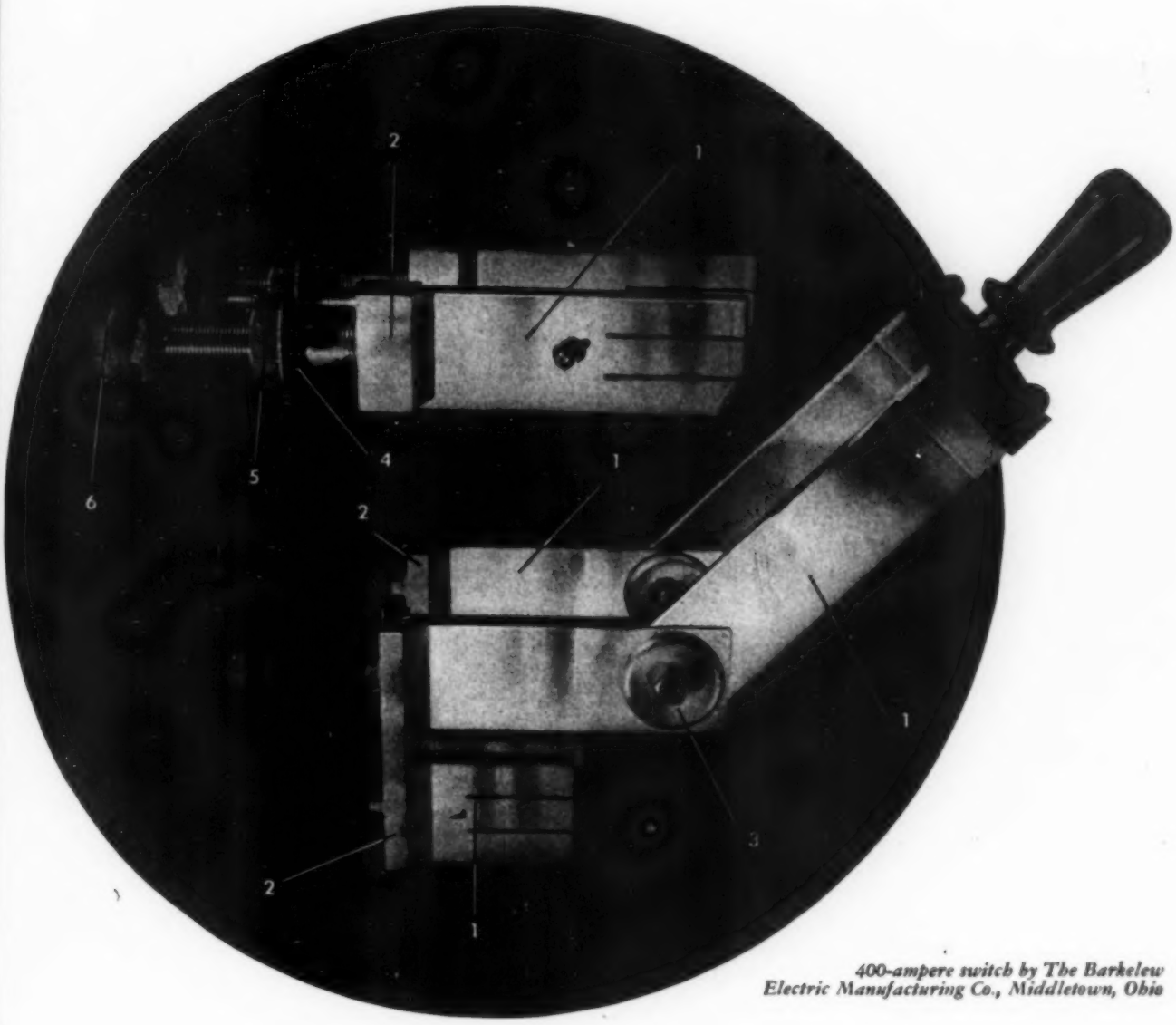
Frank B. Hubbard ⊖ has been recalled to J. H. Williams & Co., Buffalo, N. Y., from Aluminum Forgings, Inc. He is now engineer of power and maintenance.

Clyde R. Ethier ⊖, formerly assistant metallurgist, Allis-Chalmers supercharger plant, has been discharged from the Army and has taken the position of metallurgical engineer with George M. Pendergast & Co., Milwaukee.

Laird Gale ⊖, formerly of Columbia Steel Co., has accepted the position of metallurgist in charge of the chemical and metallurgical laboratories at the U. S. Naval Station, San Diego, Calif.

After nearly 37 years of active service, mostly in the Ordnance Department, **H. H. Zornig** ⊖ has retired from the U. S. Army and has joined the staff of the research laboratory, General Electric Co., as a research engineer in the Hanford division, Richland, Wash.

V. B. Bullen ⊖, following his return from service, has joined the Gross-Feibel Safe Co., Hillsboro, Ohio, as production manager and treasurer.



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Materials were very carefully chosen in designing this switch. For example, the hinge block for the high clip must have two slots milled in it to receive the clip leaves; Revere Free-Cutting Copper was selected for its superior machining characteristics. Slots in the lower hinge blocks are sawed all the way through, and here Revere Hard Drawn Electrolytic Copper is suitable.

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PERSONALS

Reynolds Metals Co. has transferred **W. F. Hunt** from the Louisville plant No. 8 to the Phoenix extrusion plant, where he is chief engineer.

Lloyd E. Barnes has started his own plant, Barwin Co., manufacturing electroplating equipment and heat treating fixtures. He was previously associated with the Clinton Engineering Project at Oak Ridge, Tenn.

Jack Newkirk, after his release from the armed services, has enrolled at Carnegie Institute of Technology, Pittsburgh, where he is taking graduate work in metallurgy.

James H. Moore, formerly in the Air Corps, has joined the National Research Corp., Boston, Mass., as physical metallurgist.

Howard C. Beede has become associated with the Standard Oil Co. of California in the materials laboratory at Richmond, Calif. He has just completed work for his master's degree at the University of Illinois.

Edward M. Wallace is now metallurgist at the Vulcan Safety Razor Corp., Maplewood, N. J.

Harold A. McCrensky, formerly in the research division of the Western Brass Mills, has joined M. Kaufman Associates, consulting industrial and management engineers, of Fitchburg, Mass.

Donald M. Kelman has been employed as metallurgical engineer at the East Pittsburgh plant of Westinghouse Electric Corp. He was previously research metallurgist at the Heppenstall Co.

T. C. Evans has been transferred by E. I. du Pont de Nemours & Co. from the Belle works to the Sabine River works where he will take charge of the metallurgical department of the newly constructed nylon intermediates plant.

Harold B. Lewis has been employed by the Curtiss-Wright Corp. propeller division, at Caldwell, N. J. as a metallurgist in the engineering materials laboratory.

R. L. Stephenson has been transferred by Borg Warner Corp. to the Wisconsin Transmission Div. as heat treat engineer.

G. M. Letson has returned to his position as vice-president of Letson & Burpee, Ltd., after an absence of 6½ years with the Canadian Army.

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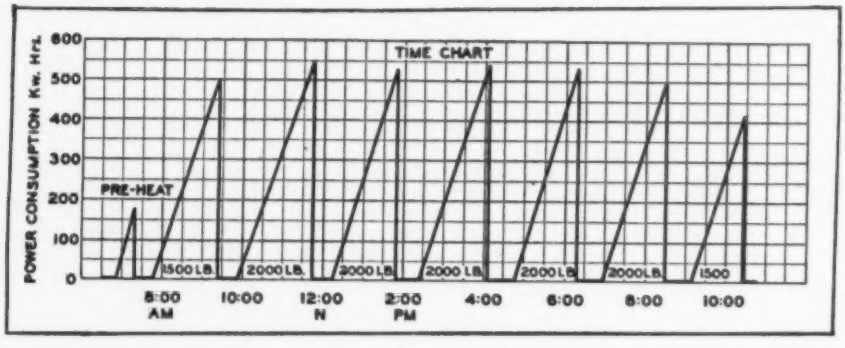

SUMMARY: HOURS OPERATION, 15; NO. HEATS, 7; TAPPING TEMPERATURE, 2900°F. TOTAL METAL MELTED, 13,000 LBS.; TOTAL Kw Hrs. USED, 3735; Kw Hrs. PER TON, 575.

Facts speak for themselves—and here are the facts taken from a daily operating record covering a typical working schedule of a Detroit Electric Furnace. In 15 hours, a 1000 lb. rated capacity Type AA Detroit Electric Furnace melted 7 heats of white iron for a total of 13,000 lbs. Allowing a half hour pre-heat period, as shown in the graph above, that means nearly a half ton of metal was produced every hour. Here is proof that Detroit Electric Furnaces are fast melting and efficient. They produce a superior metal, because their unique construction permits close control over time, temperature, composition, and other vital melting factors. Their closed chamber reduces dirt and fumes to a minimum. They are easy to operate, inexpensive to maintain. Write for further facts on how Detroit Electric Furnaces will speed economical melting of ferrous and non-ferrous metals in your own foundry.

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PERSONALS

Arthur E. Inman has joined staff of the University of Kansas Research Foundation after 6½ years with the Army. He was commanding officer of the Sunflower Ordnance Works of the Army's Rocket and Smokeless Powder Plant at Lawrence, Kan.

C. S. Hilcox has joined C. H. Birckkoltz, Bogota, Colombia, and will make steel purchases for this organization from his offices in Tavistock, Ontario.

Waldemar Naujoks, author of the "Forging Handbook", has resigned his position as chief engineer of the Steel Improvement & Forge Co., Cleveland.

L. E. Earnest has been made general plant manager of Gunnison Homes, Inc., New Albany, Ind.

SKF Industries, Inc., announces the appointment of **William L. Aiken** as senior division engineer in charge of the automotive and marine department. Mr. Aiken was previously executive engineer of the Autocar Co.

Clarence H. Sample, formerly chief engineer of Rheem Research Products, Inc., has joined the electroplating section of the nickel sales department of the International Nickel Co., Inc., New York.

William H. Lenz, formerly chief metallurgist of the Fansteel Metallurgical Corp., has become metallurgical director of Permo, Inc., Chicago.

Following the sale of the Elizabeth, N. J., plant of Lidgerwood Manufacturing Co., **J. S. Foster** has resigned from the company and has organized his own consulting business for design and installation of cableways and hoisting equipment in New York City.

Walter J. Broeking, formerly director of testing and research for R. G. LeTourneau, Inc., Peoria, Ill., has been appointed dean of the LeTourneau Technical Institute at Longview, Texas.

E. C. Babson has resigned from the Union Oil Co. and is now associated with the Peerless Pacific Co., Portland, Ore.

Pittsburgh Lectrodryer Corp. announces the appointment of **Wendell V. Kincaid** as sales representative in the Tennessee Valley with headquarters in Knoxville. Mr. Kincaid has been with the company since 1942.

Kodak

It magnifies time...

The Eastman High-Speed Camera provides a direct approach to "high-speed" engineering problems

If you're studying engineering problems that involve action too fast for the human eye to register, you can get the visual facts you need with the Eastman High-Speed Camera, Type III.

Here's what it does . . . It takes motion pictures at 3000 frames a second. Then you project them at only 16 frames a second . . . thus magnifying "action time" almost 200-fold.

Here's what it does for you . . . It enables you to see, analyze, and measure flame phenomena, chatter and vibration in machine elements, movements of fluids. Shows you these and many other types of swift, blurred, transient action as slow, clear, continuous motion.

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"not only to serve today, but to anticipate tomorrow"
Wm. B. Given, Jr.

MEEHANITE CASTINGS
as made by BRAKE SHOE

...help to avoid vibration
in P&W Vertical Shapers

IN making vertical shapers in 6-inch and 12-inch sizes, Pratt & Whitney Division, Niles-Bement-Pond Company took all possible steps to avoid vibration. One very important decision was the selection by P & W metallurgists of Meehanite castings made by Brake Shoe for all main castings of both shapers, including the bases.

Superior damping capacity at a high stress range was only one of many requirements when these castings were chosen. Included also must be rigidity and the required high degree of strength which Meehanite castings also provide. As a result, smooth easy operation is promoted and accuracy maintained.

Physical and metallurgical properties that are "made to order" are available to users of Meehanite castings on a production-schedule basis. The range of types is so wide that *your work specifications are the casting specifications.* And, like a good machine tool, Meehanite castings made by Brake Shoe are soundly based – based on the experience, knowledge of foundry technique, and the research-plus-production facilities of the entire Brake Shoe organization.

Brake Shoe
BRAKE SHOE AND CASTINGS DIVISION
230 PARK AVE., NEW YORK 17, N. Y.

PERSONALS

After 27 years with the Army and Navy, **W. J. Jeffries** has retired from government service and is engaged in a private consulting practice.

J. M. Keating has purchased and is operating the Thorp Telephone Co., Thorp, Wis.

F. N. Darmara has left his position as metallurgist at the aircraft engine research laboratory, National Advisory Council on Aeronautics, Cleveland, and has joined the staff of the U. S. Steel research laboratory at Kearny, N. J.

Sylvania Electric Products, Inc., announces the appointment of **Igor N. Zavarine** to its metallurgical research staff. Dr. Zavarine was professor of physical metallurgy at Massachusetts Institute of Technology from 1930 to 1940.

Paul R. Pollock has been named manager of the Denver office of the Allis-Chalmers Manufacturing Co. following 11 years' association with the company in the Washington, D. C., and Denver offices.

James B. Fisher, sales representative for the Superior Steel Corp., has been transferred from Pittsburgh to Detroit.

L. D. Kunsman has accepted the position of chief inspector of motors for the newly acquired electric vacuum cleaner division of General Electric Co. in Cleveland.

H. T. Harrison has been assigned to the Air Materiel Command at Wright Field, Dayton, Ohio, where he is doing research and development work on new magnesium alloys.

William A. Mays is now metallurgical engineer at the Amarillo Helium Plant of the U. S. Bureau of Mines at Amarillo, Texas.

Following his discharge from the U. S. Navy, **Harrison S. Gruber, Jr.** has become research metallurgist at the Reynolds Research Institute, Glen Cove, N. Y.

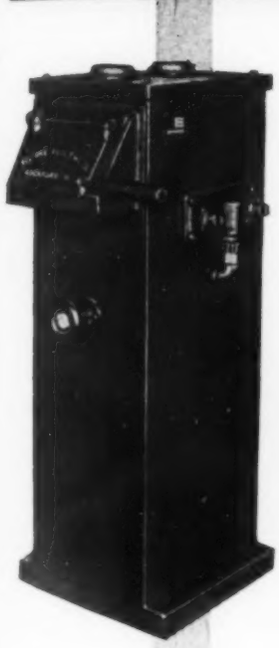
Arthur B. Tesmen, formerly metallurgist at Crucible Steel Co. of America, is now development and research engineer in charge of the welding laboratory of North American Philips Co., Dobbs Ferry, N. Y.

H. J. Antosz has accepted a position as mechanical engineer at the Bureau of Reclamation, Billings, Mont. He formerly worked for the H. K. Ferguson Co., Oak Ridge, Tenn.

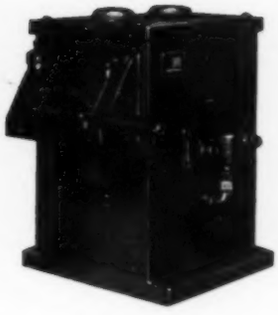
eclipse

SMALL GAS-FIRED

SHOP FURNACES



Automatic Shop Furnace



No. 1-B Oven Furnace

No. 1-F Oven Furnace

No. 814 Oven Furnace

★ The Eclipse Small Oven Furnaces are now available in a variety of sizes and designs. Each model is gas-fired, completely assembled. Each requires but little floor space . . . Consisting of an oven furnace, a proportional mixer suitable for use with low pressure air and gas . . . Eclipse Small Furnaces prove ideal for intermittent use in small tool rooms . . . Write for Bulletin D-1 completely describing these new Eclipse models. Choose the one best suited to your needs.

Eclipse Fuel Engineering Company
ROCKFORD ILLINOIS

McKee Eclipse

PERSONALS

Rolland Stentz has been transferred from the Jersey City apparatus research department of Air Reduction Co. to the Detroit district as technical sales representative.

William T. De Long, recently discharged from the Army, is now a metallurgist at the Induction Heating Corp., New York City.

Robert B. Mears is now electrochemist in the United States Steel Corp. Research Laboratory, Kearny, N. J.

William James Galbraith is with the research laboratory of the Minnesota & Ontario Paper Co. as a draftsman.

Edward Epremian has taken leave of absence from the metallurgical section of the General Electric research laboratory for graduate study at Rensselaer Polytechnic Institute.

R. S. Niccolls, who accepted a regular Army commission as first lieutenant in July, now has the temporary rank of major at University of Michigan as assistant professor of military science and tactics.

F. H. Welsh has been appointed district field engineer for Chicago by the Beryllium Corp., Reading, Pa. He was formerly with the Goodyear Aircraft Co.

Carl Ludwig is now chief engineer for Adamson United Co., Akron, Ohio.

Howard H. Rickabaugh, formerly Chicago representative of the western railway department of Crucible Steel Co. of America, has been transferred to Albany, N. Y., where he will serve as northeastern railroad representative.

Wheelco Instruments Co. announces the appointment of **John E. Anderson** as manager of the new Indianapolis sales and service office.

L. E. Householder has been transferred by the Reynolds Metals Co. to the Grand Rapids, Mich., plant, which was recently leased from the U. S. government. He holds the position of chief plant metallurgist.

Barton O. Baker has been recalled into active military service and is at present assistant ordnance officer at Fort Jackson, S. C. He was formerly with the tractor works of the International Harvester Co., Chicago.

George J. Moeller, formerly works manager of Dazey Corp., St. Louis, is now plant manager of Consolidated Tool & Products Co., Los Angeles.

Having been released from active duty with the Navy, where he served for five years as chief of the gun design subsection of the Navy's Bureau of Ordnance, **Blake D. Mills, Jr.**, has been appointed associate professor of mechanical engineering at the University of Washington, Seattle.

William L. Drake, formerly in the metallurgical department and research laboratory of American Rolling Mill Co., is now metallurgist for Halcomb Works, Crucible Steel Co. of America, Syracuse, N. Y.

Geoffrey J. Siegel, formerly stationed at the U. S. Naval Research Laboratory, Washington, D. C., is now doing mechanical design work for the Austin Co., Cleveland.

Following his discharge from the Army Engineering Corps, **E. P. Vollherbst, Jr.**, has joined the Westinghouse Electric International Co., New York, as industrial X-ray engineer.

Charles A. Haas has been transferred by Wyatt Metal and Boiler Works from the Dallas plant to the Houston plant to assist in setting up a metallurgical control laboratory.

Francis G. Jenkins, after resigning from the Eastman Kodak Co., has been appointed director of the price analysis methods section of the purchasing division, Ford Motor Co., Dearborn, Mich.

After his release from the U. S. Navy, **H. A. Mayo, Jr.**, has joined the S. Morgan Smith Co., York, Pa., as a junior engineer.

R. J. Prout, formerly at the Gary plant of the Carnegie-Illinois Steel Corp., has been appointed supervisor of the metallurgical laboratory of Geneva Steel Co., Geneva, Utah.

Frank W. Wilson, formerly on the faculty at the University of Michigan, has accepted a position as superintendent of design and construction for the General Electric Co., Hanford Engineer Works, Richland, Wash.

B. W. Duncan is doing graduate work at Carnegie Institute of Technology, Pittsburgh, following his release from the Navy.

Arthur P. Siewert has joined the research laboratory staff of the Linde Air Products Co., Tonawanda, N. Y.

Now... Higher Selectivity at Lakeside

with

G-E High Frequency Induction Hardening

The General Electric ELECTRONIC INDUCTION HARDENING equipment, recently installed in our plant, is an important addition to our many services. It offers wide selectivity and is the perfect complement to our other diversified methods of hardening. Call for full information.

Our Services: Electronic Induction Hardening, Flame Hardening, Heat Treating, Bar Stock Treating and Straightening (mill lengths and sizes), Annealing, Stress Relieving, Normalizing, Pack, Gas or Liquid Carburizing, Nitriding, Aerocasing, Chapmanizing, Cyaniding, Sand Blasting, Tensile and Bend Tests.

THE Lakeside Steel Improvement Co.

5418 LAKESIDE AVE., CLEVELAND 14, OHIO HENDERSON 9100

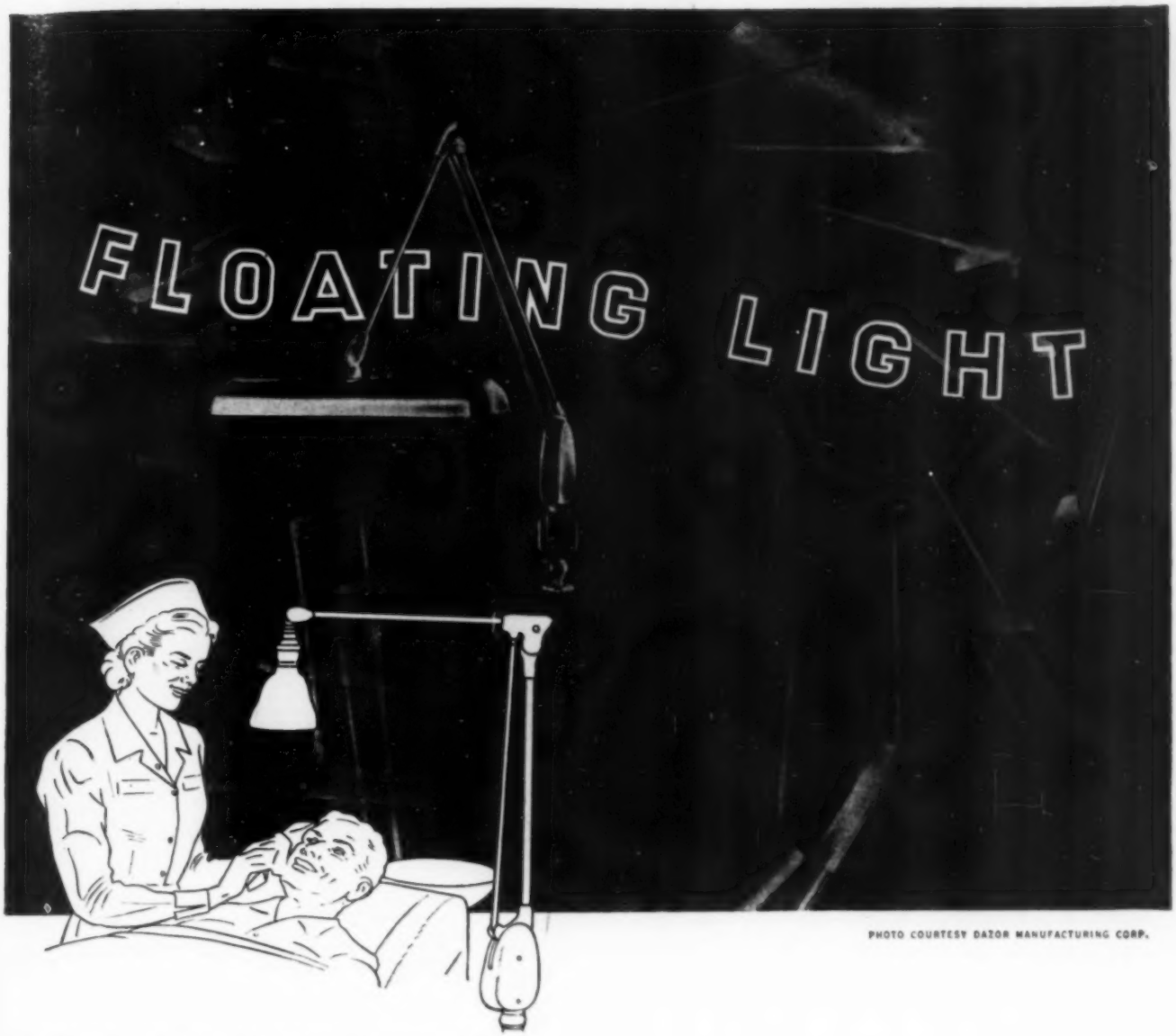


PHOTO COURTESY DAZOR MANUFACTURING CORP.

Localized lighting, "floated" into position as easily and quickly as you move your arm! Push, pull, raise or lower it . . . swing, turn or tilt it . . . the Dazor fluorescent or incandescent lamp "freezes" into position instantly, without tightening or locking.

The double arms of these ingenious floating lamps—and the vertical section of the pedestal models—are built of OSTUCO Steel Tubing, selected for its strength-without-weight advantages. Here, as in countless other applications, OSTUCO research, testing, design and manufacture have combined to solve a complex manufacturing problem.

Precision craftsmanship and quality of product make OSTUCO a welcome partner in the search for more efficient, more economical production of a variety of products, many of which are, similar to yours.

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THE OHIO SEAMLESS TUBE COMPANY

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PERSONALS

The Aluminum Co. of America has appointed **R. E. Millard** as sales representative in Denver. Mr. Millard has been associated with the company's sales department since 1929.

E. D. Walker has been recently employed as assistant metallurgist with John Deere Dubuque Tractor Co., Dubuque, Iowa.

B. R. Miller has been appointed senior mechanical engineer of Sverdrupa Parcel Consulting Engineers, St. Louis, Mo.

I. K. MacGregor has been appointed sales manager of the Campbell, Wyant and Cannon Foundry Co., Muskegon, Mich.

Phillip L. Banfield has been employed in the science department of the General Motors Institute at Flint, Mich., as an instructor of physics and metallurgy.

E. A. Kachik, formerly research assistant in metallurgy at Pennsylvania State College, has returned to du Pont's engineering research laboratory at Wilmington, Del., as metallurgical engineer.

Olof G. Lorentzson has been appointed superintendent of Bailey & Blendinger Co., Inc., Union, N. H.

Frederick J. Winsor has accepted a position as research metallurgist with the Armour Research Foundation, Chicago. **Roy D. Haworth, Jr.,** has also joined this organization to supervise foundry metallurgical research.

On discharge from the U. S. Navy, **Stanley T. Johnson** has become sales engineer for U. S. Steel Export Co.

F. A. Purdy, formerly manager of the Rochester district office of Joseph T. Ryerson & Son, Inc., is now manager of the Los Angeles plant.

Lewis N. Rohrbach has been promoted to chief of sales control, customers' service division, War Assets Administration, in Detroit.

Upon release from active duty with the Navy, **D. A. Griffin** has returned to General Electric Co., Schenectady, where he is a student in the patent attorney training course.

Harry F. Ehrnst is now associated with the Chase Brass & Copper Co., Waterbury, Conn., as mill research assistant.

WARREN
PROPANE-BUTANE

FOR INDUSTRIAL HEATING

Warren is one of the nation's oldest and largest manufacturers of Propane and Butane. These low-cost, high-purity, gaseous fuels are recognized by manufacturing and industrial plants throughout the world for an ever-growing number of industrial uses. The uniform high quality of Warren's Propane and Butane, together with the experience and engineering ability of this pioneer organization, are available to you. Contact your nearest Warren office.

WARREN PETROLEUM CORPORATION
TULSA, OKLAHOMA
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CLARK

Gives Continued Accuracy, Rapid Measurements

THE CLARK has everything you want in a hardness tester—direct reading precision dial, durable construction, ease of servicing. Three standard models shipped complete with weights, dust protectors, diamond and steel penetrators, test blocks, and anvils.

CLARKATOR CHECKS DIAL INDICATORS with micrometer speed and sine bar accuracy. Easy to operate—just four simple steps. Complete instructions, permanently fastened to base.

MASTER DIAMOND CHECKING SET eliminates hardness tester errors. Consists of a master diamond penetrator and two test blocks. Precision is assured over a long period because the set is used only for checking. Furnished in leather case.

Learn the truth about hardness testing! This 20-page reference manual (right) contains information on history, theory, practice, and equipment for modern hardness testing. Available to executives without charge. Write Dept. MMS today!

CLARK
INSTRUMENT, INC.
10200 Ford Road • Dearborn, Mich.

REDUCE HEAT-HOUR COSTS

In use by a prominent, mid-western automotive plant, these pots of ¼" welded Nichrome, on trays of cast Chromax, reduced dead load and allowed a shorter heating cycle.

with

DRIVER-HARRIS Welded NICHROME* Equipment

Heat-treating fixtures of all kinds — basket, boxes, trays etc. — have less dead weight, higher heat transfer and permit a shorter heating cycle, when fabricated from Driver-Harris Welded Nichrome.

These and other cost reducing factors are possible because Nichrome, in its malleable form, permits the use of a lighter, thinner, welded construction. In addition, the high heat and corrosion-resisting qualities of D-H Nichrome assure a longer-than-average equipment life resulting in still greater production economies.

If you would like to know how D-H Welded Nichrome heat-treating equipment can reduce heat-hour costs in your operation get in touch with our engineers. As manufacturers of the well-known "NICHROME" Castings, we are prepared to recommend either castings or weldments or a combination, whichever is indicated by your conditions of operations.

NICHROME* — CHROMAX* — CIMET*
are made only by

DRIVER-HARRIS DESIGNS, ENGINEERS and MANUFACTURES a complete line of heat-treating equipment from furnace parts to carburizing retorts and muffles — also over 80 *electrical heat and corrosion-resistant* alloys for the Electrical and Electronic Industries.

The 3 high heat-resisting nickel-chrome cast D-H alloys — NICHROME* — CHROMAX* — CIMET* are fully described in this catalog F-40. Write for a copy.

*Trade Mark Reg. U.S. Pat. Off.

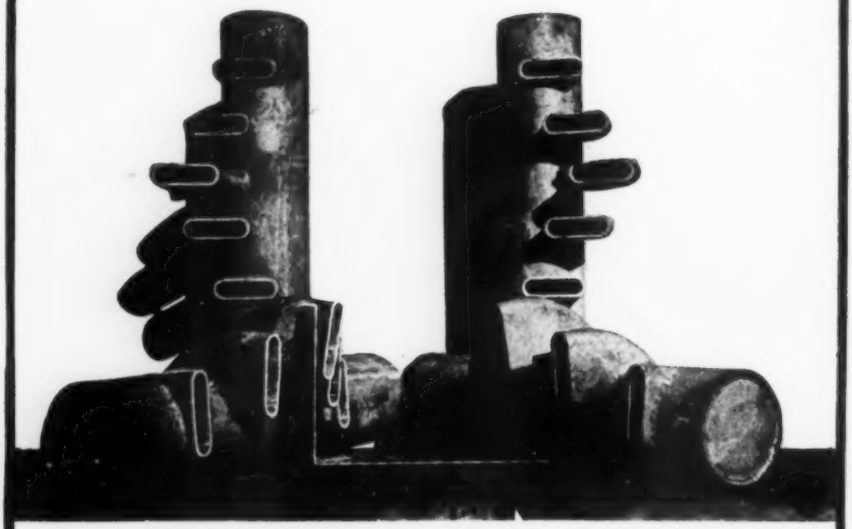
Driver-Harris COMPANY
Exclusive Manufacturers of Nichrome
HARRISON, N. J.

BRANCHES: Chicago • Detroit • Cleveland • Los Angeles • San Francisco • Seattle

DURALOY

Queer Looking, Aren't They?

They're the left and right burners for an ingot treating furnace, each weighing about 600 pounds, alloyed with about 25% chromium and 12% nickel. The manifold openings were cast separately and then welded onto the centrifugally cast pipes.



These burners are typical of the countless different shapes and sizes of high alloy castings made for Duraloy and Duraspun customers. *To every job* we bring the experience that comes from working in this field continuously and exclusively since 1922. *To every job* we bring the facilities of one of the most modern high-alloy foundries in the country.

If you would like suggestions as to the proper alloying for your chrome-iron and chrome-nickel casting requirements, our metallurgists will be glad to help.

THE DURALOY COMPANY

UNDERWATER CUTTING*

IN 1942 the Navy Department decided to develop the arc-oxygen instead of the oxy-hydrogen cutting process in order to eliminate the use of highly inflammable hydrogen; the former is also a more efficient torch. The modernized arc-oxygen method uses covered steel or ceramic tubes as electrodes with the normally available 300-amp. welding generators. Oxygen consumption has been considerably reduced from that found necessary with the earlier types of electrodes, while the cutting rate has been greatly increased. The power requirement has been approximately halved. The new torches permit rapid and safe replacement of electrodes independent of visibility.

In arc-oxygen cutting, the tip of the electrode is incandescent and thus exposed to the effects of heat and oxidation. Although copper-base alloys and cast iron do not oxidize readily, steel is more suitable for electrodes because of its higher melting point. Three types of coatings are used for the hollow steel electrodes. All serve as an electric insulation and maintain a protective thimble around the arc. Regardless of the type of covering used, the service life of a covered, tubular steel underwater cutting electrode averages 1 min.

In modernizing the arc-oxygen method, all efforts were concentrated to simulate the simplicity of oxy-acetylene cutting in air. Accordingly, a technique was developed called the "drag technique", which consists merely of pressing the electrode against the advancing lip of the cut. The arc-oxygen method of underwater cutting with steel tube electrodes is adaptable to cutting steel in air. Either the drag technique or a short arc technique as in welding may be used. Cutting rate is rapid and the neatness of the cut is intermediate between those obtained with the oxy-acetylene and the carbon-arc methods. The arc-oxygen procedure is also applicable to cutting, in air or under water, cast iron, stainless steel and the nonferrous metals, but the drag technique is not. *(Continued on p. 306)*

*Abstracted from "U. S. Navy Developments in Underwater Cutting", by Bela Ronay and Cyril D. Jensen. *Welding Journal*, V. 25, March 1946, p. 201 to 209.

Advertisement

FEBRUARY, 1947

R-S FURNACE FACTS

ISSUED MONTHLY BY R-S PRODUCTS CORPORATION, PHILADELPHIA 44, PA., FOR THOSE CONCERNED WITH QUALITY HEATING OF METALS

Labor-saving R-S Furnaces

A piece in the paper recently said labor costs are rising. So don't just *order* a furnace! Talk with R-S Engineers and see if we can find a way to do the heating and also save labor costs.

Note the labor-saver below . . . an R-S heat-treating furnace used by Parish Pressed Steel Company for auto truck side frame members. It's a walking-beam type which charges sidewise into 49' 6" heating chambers, discharges endwise through a small side door. Saves labor, saves space! Gives the same production with a smaller furnace than the one previously used.

A historic example is the job R-S built for American Gear and Manufacturing Company (see December 1946 FURNACE FACTS). This 4-unit R-S Furnace ate up automobile axles, steering-knuckles and other hardware as a hen gobbles corn, and put them through a harden-quench-and-draw cycle for the first time by fully mechanized means. Such an operation, now fully automatic, called for manual labor at five points before R-S came up with its revolutionary labor-saving design!

For another example, we show a continuous brass billet heating furnace. It's a beauty, and too bad we haven't room for more pictures of it! The problem here was to get the billets into a furnace raised six feet from the floor. R-S solved it with a storage pit and a heavy self-loading conveyor which fed the billets to the walking-beams which carried them through the furnace. Capacity of 70 billets per hour or 28,000 pounds.

R-S Engineers are constantly at work on problems which combine heat treating with reduction of labor costs and increase of production.

Meet the President!

"Bill" Borbonus is one of the youngest old-timers in the furnace industry. His entire business career has been spent with R-S Products. It was in 1924 that he came from school and set his foot on the bottom rung of the ladder. Three years later he became Purchasing Agent and in 1931 added the title Treasurer. Following several years in sales-work, Bill was elected President in August 1939, proving, to his satisfaction at least, that a rolling stone gathers no moss.

WILLIAM E. "BILL" BORBONUS

However, since 1939 no moss has been gathering on the R-S organization. The old plant at Germantown Avenue and Berkley Street has expanded as far as Apsley Street. Physical expansion of space and equipment has been balanced by the increase in skilled manufacturing personnel and the steady development of the Engineering Department. This has put R-S in a position to execute multi-million dollar contracts, many of which have been handled in recent years.

Bill is now approaching his Silver Anniversary with R-S Products and looking forward to his Golden Anniversary, counting the years between as an opportunity to indulge his hobby of making friends throughout the Metal Industry.

He feels that the future success of the company will rest as its present repute does, securely on the simple policy of sound engineering and conscientious attention to the customer's long-term interest.

A heater named Barney Gilfoyle
Said, "I note that according to Hoyle,
R-S Furnaces use
Any fuel I choose
Whether gas or electric or oil."

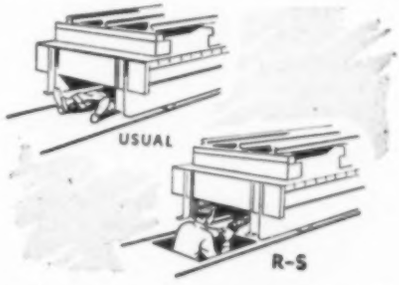
R-S specializes, to be sure, but what we specialize in is Industrial Furnaces, Industrial Heating. We do not specialize in gas, oil, or electricity. We build your furnace to use the most practical fuel.

P-111

R-S Car Hearth Wheels Get their Grease Without Squeaking

A good furnace designer takes pains to ascertain the standard type of pressure lubricating devices used in the plant where his car-hearth furnace is being installed. He then uses the same type of equipment so that no special tools are required to lubricate the new running gear.

R-S does this, of course, but then we go a step further! R-S plans to make it easy for the workman to lubricate wheels, bearings, and electric motor drive. Unfortunately, most bearings are so placed that the workman has to stand on his head or squeeze into awkward positions to hitch his grease-gun to the lubricating ports. Such inconveniences are an irresistible invitation to neglect. R-S plans a lubricating pit so the workman can work from under the car in full standing position and reach all bearings with a minimum of effort. Result: R-S wheel-bearings and electric motor drive are lubricated when and as they should be . . . all of them . . . and maintenance costs



are kept down. It's an important consideration when you realize that 8.2¢ of every revenue dollar goes into maintenance, and it's rising in cost! See 'FURNACE FACTS', January issue.

UNDERWATER CUTTING

(Continued from page 304)

The ceramic tube electrodes were developed to overcome the disadvantages of the steel tube electrodes (short life, low cut-burn-off ratio, narrow kerf). The core of the ceramic tube electrode is composed of highly refractory, stable oxides. It is surrounded by a $\frac{1}{32}$-in. mild steel shroud applied by metal spraying. Finally, the tube is wrapped in an electrical insulating sleeve and waterproofed. Cutting technique differs from that used with the covered steel tubes in that the ceramic tubes are applied with a light touch. The kerf is not as clean as with steel tubes, but it is wider. Ceramic tube electrodes outperform steel tubes in cutting thin and medium thick steel plates, but the steel tube electrodes are more efficient in cutting steel over $\frac{3}{4}$ in. thick and perform better with alternating current. The ceramic tubes also have the advantages of better maneuverability and lighter weight.

Ceramic tube electrodes are also suitable for underwater cutting of stainless steel, copper and nickel-base alloys and cast iron. They can be used advantageously for cutting steel and these other metals in air. A recent development is the technique for removing defective austenitic weld metal from deep grooves in any position. It is considerably slower than the carbon-arc method for this purpose, but it is extremely simple.

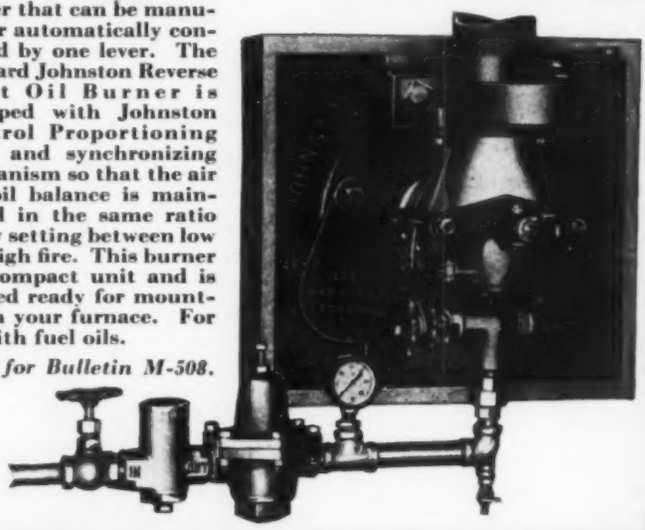
A procedure has been developed for emergencies where covered, mild steel welding electrodes are used for cutting metals under water. This process is superior to the arc-oxygen process for cutting cast iron and nonferrous metals. Since oxygen or air is not available for removing the molten metal, the operator must compensate for it by manipulation. Practically any type of covered electrode, waterproofed, is applicable. The rate of progress in cutting steel plate is substantially lower than with arc-oxygen cutting. Since the usual electrode holders cannot be fully insulated, an all-plastic shielded electrode holder has been developed.

Electric underwater operations using any of the above procedures may be extremely hazardous, especially in sea water. Safeguards must be provided to assure reasonable safety for the operators.

JOHNSTON PROPORTIONING
Reverse Blast
OIL BURNER

Designed to fill the demand for a simplified oil burner that can be manually or automatically controlled by one lever. The standard Johnston Reverse Blast Oil Burner is equipped with Johnston Fueltrol Proportioning Valve and synchronizing mechanism so that the air and oil balance is maintained in the same ratio at any setting between low and high fire. This burner is a compact unit and is shipped ready for mounting on your furnace. For use with fuel oils.

Write for Bulletin M-508.



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JOHNSTON MANUFACTURING CO.
2825 EAST HENNEPIN AVE
MINNEAPOLIS 13, MINN.
ENGINEERS & MANUFACTURERS OF INDUSTRIAL HEATING EQUIPMENT

TENSILE PROPERTIES AS AFFECTED BY PRESSURE*

THE EFFECT of hydrostatic pressures on four stainless steels (Type 410, 430 and two samples of Type 302) and of a high-carbon steel quenched and tempered to hardnesses from Rockwell C-48 to 63 was investigated. Previous work on low-alloy steels at hardnesses below Rockwell C-50 showed that the pressure effects on these steels falls approximately into a one-dimensional pattern, the behavior being determined by the hardness or absolute magnitude of the yield point at atmospheric pressure.

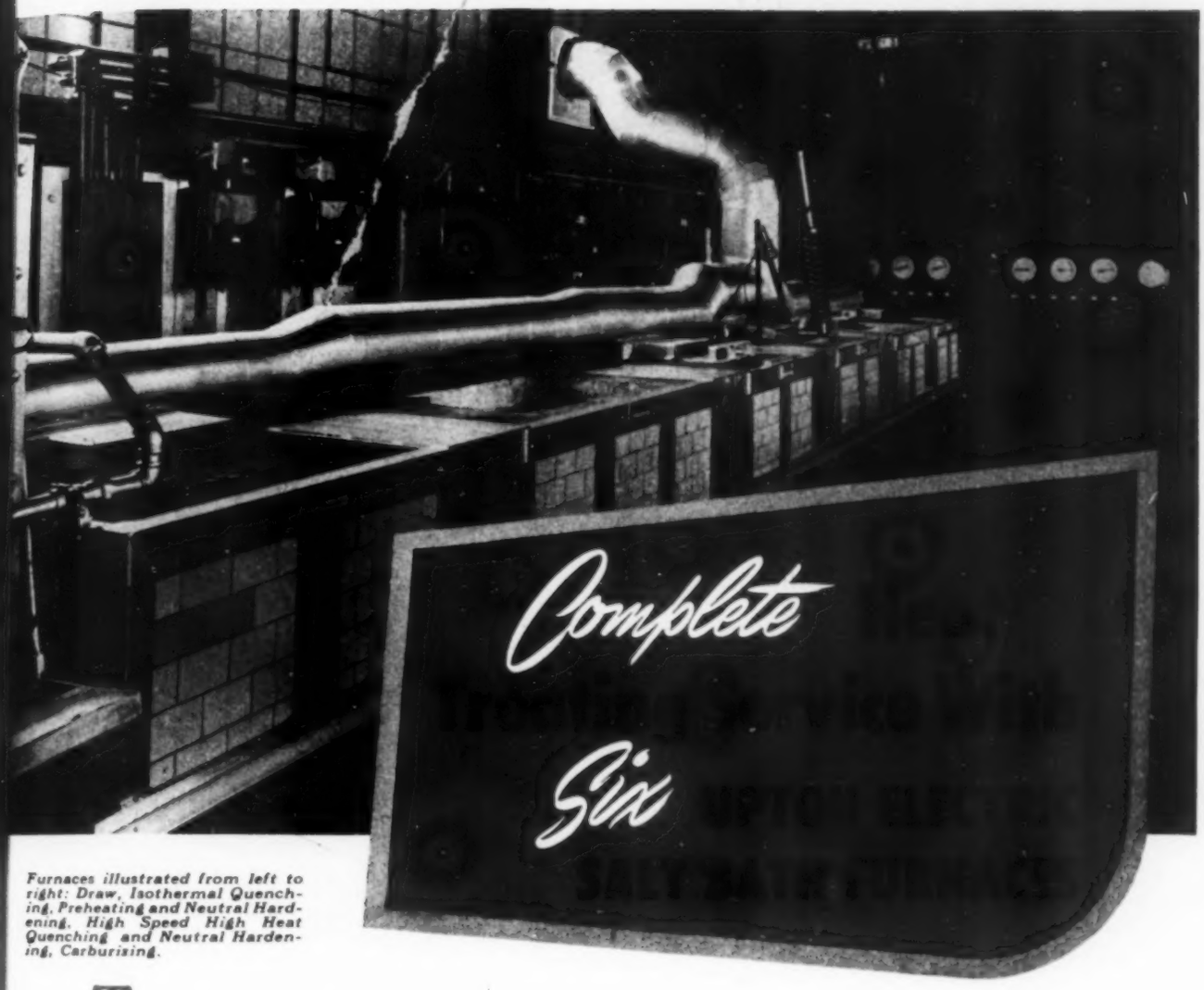
The strain hardening curves of the different grades of steel form a fan-shaped family of noninteresecting lines, the slope of the line being higher the higher the absolute value of stress, with the exception of the two samples of Type 302. For these two specimens, the slope of the strain hardening line is higher than would be expected from the tensile strength at atmospheric pressure. That is, these two steels harden at an abnormally rapid rate.

Curves showing the effect of pressure on ductility indicate that all the steels investigated, except Type 302, fall into the same family of curves as the steels previously investigated; increase of ductility under a given increment of hydrostatic pressure is greater the lower the absolute tensile strength. Type 302 is an exception, since the increase of ductility of the two heats under hydrostatic pressure is abnormally low.

A search was made for a possible criterion of rupture by plotting various relevant stresses against the strain at fracture. No criterion was good under all conditions. The constancy of the *(Cont. on p. 310)*

*Abstracted from "The Tensile Properties of Several Special Steels and Certain Other Materials Under Pressure", by P. W. Bridgman. *Journal of Applied Physics*, V. 17, March 1946, p. 201 to 212.

1926—pioneered the first practical controlled-atmosphere furnace



Furnaces illustrated from left to right: Draw, Isothermal Quenching, Preheating and Neutral Hardening, High Speed High Heat Quenching and Neutral Hardening, Carburising.

THE Dayton Forging and Heat Treating Co. selected Upton furnaces to provide *complete* heat treating service for its customers. Six Upton Electric Salt Bath Furnaces with Sealed-In Electrodes assure the uninterrupted and uniformly accurate heat treating of any work between 300° and 2500° F.

The six furnaces in this illustration are all 54″ deep! Sealed-in electrodes at the bottom of each furnace (24″ below floor line) eliminate changing of electrodes, reduce surface area—and resulting losses from radiation—remove all chances of burning or shorting work.

Upton furnaces can be built to Any Size to accommodate Any Type of work. Send for recommendations—without obligation on your part.

Upton ELECTRIC FURNACE DIV.

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TODAY—providing the most advanced types of controlled-atmosphere furnaces

—and on FORGINGS for Jet Engines

"Certain Curtain" gives scale-free pre-heating at

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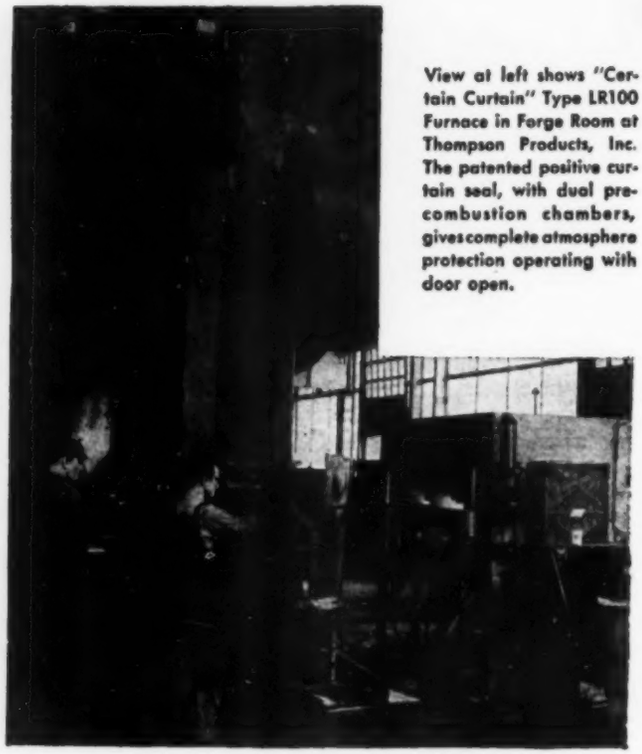

View at left shows "Certain Curtain" Type LR100 Furnace in Forge Room at Thompson Products, Inc. The patented positive curtain seal, with dual precombustion chambers, gives complete atmosphere protection operating with door open.

Through highly accurate forging methods, Thompson Products, Inc. have eliminated many hours of hand fininishing formerly required to bring jet turbine blades to the required fineness of finish and accuracy of dimension.

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In the production of the forged blades, control of temperature, uniform heating and elimination of scale are extremely essential. "Certain Curtain" furnaces are used to pre-heat the blades to forging temperature, the exclusive features of these furnaces assuring uniform heating free of distortion, as well as complete protection from surface attack and scaling.

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Consistent uniformity free of fluctuation.
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Specialists in Fabricating and Stamping Aluminum, Magnesium, Stainless Steel and Other Light Metals.

COLGATE

TRIAXIAL LOADING

(From p. 306) mean hydrostatic tension (one-third the sum of the three principal stress components) was found to give the best indication, but under certain circumstances it may show considerable variation. Its margin of superiority over the criterion that the total fiber stress in the direction of fracture be constant at fracture was not impressive. The maximum shearing stress criterion failed by a wide margin. No criterion in terms of strain components only can possibly be valid.

Two new empirical results were found in this work. The component of hydrostatic tension on the axis of the specimen arising from necking is a linear function of the strain at fracture. Also, the line of hydrostatic tension versus strain is approximately parallel to the line of flow stress versus strain.

Aluminum, copper, bronze and brass show an even greater effect of pressure on ductility than do the mild steels. Tensile properties of a number of other materials were tested by bending slender rods under pressure. Antimony, arsenic, tellurium, borax glass, gray cast iron, limestone (uncovered) and Carboloy showed no measurable plastic deformation before breaking by bending under hydrostatic pressure. Bismuth showed large plastic effects. Hard rubber acquired great plasticity and also showed prominent time effects. Limestone, when covered by a heavy sheath of lead or copper, took a permanent plastic deformation in bending under hydrostatic pressure but the interpretation of the results is obscured by a polymorphic transition which takes place under pressure. Although Carboloy showed no plasticity in bending, it showed a bending strength under 29,000 kg. per sq.cm. There was a similar large increase of the elastic distortion which a glass-hard steel would support without fracture when under hydrostatic pressure.

The complicated nature of the conditions is shown by the fact that Carboloy will show plasticity in simple compression under pressure although it shows no plasticity in bending. Limestone is also markedly different in plasticity in simple tension and in bending.

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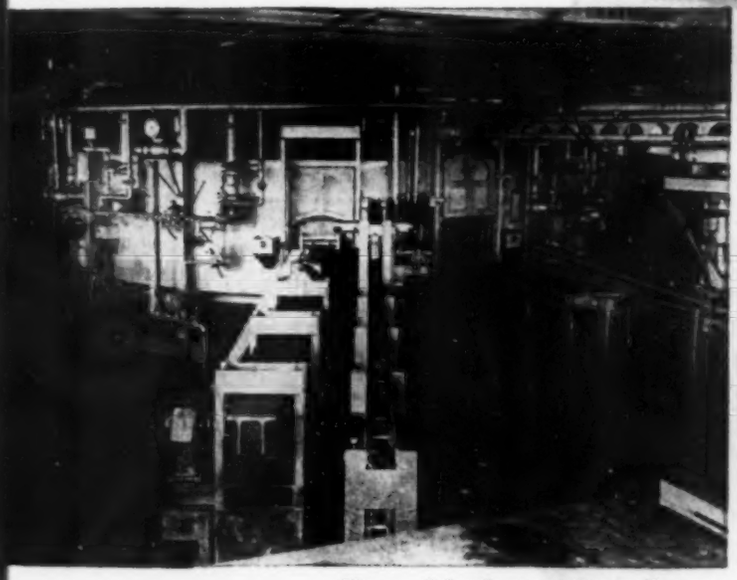
Picture of 4 small Salem Rotary Furnaces under construction in 1946.

Get all 4 *with Salem Rotary Furnaces*



Picture of doughnut type Rotary Furnace and handling mechanism designed and built by Salem in 1946.

Having effected definite savings, increased production, and high quality results for the ferrous field, Salem has proved the adaptability of its large rotary furnaces in the non-ferrous field, too. Salem furnaces are designed with capacities from one ton to over 70 tons per hour to handle and heat the most delicate and sensitive grades of metals. Remember, please, that in addition to effecting low scale losses, low maintenance costs, high quality, and fast production, Salem also shows LOW HANDLING costs resulting from Salem automatic charge and discharge design which requires *one man only!* Let us discuss furnaces with you—write today.

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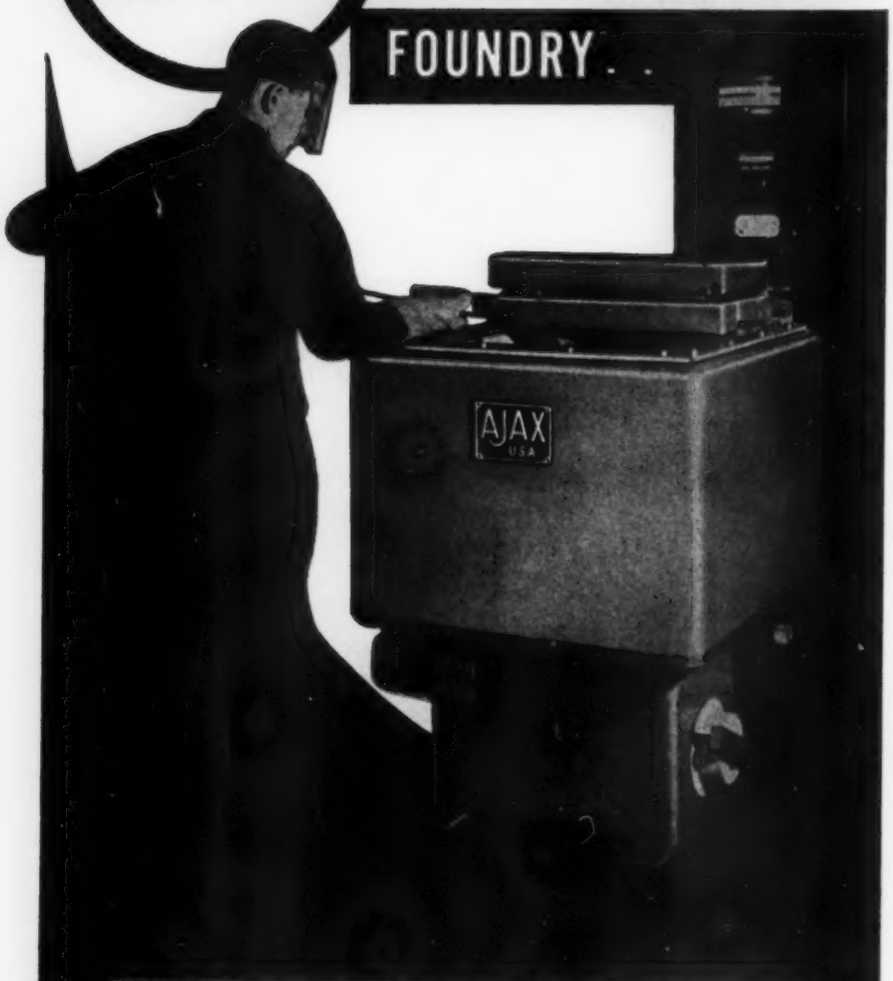

THE AJAX-Tama-Wyatt Low Frequency Induction Furnaces are now made in small sizes with capacities ranging from 20 to 35 kw.

Their operation is based on the induction principle whereby energy is transmitted to the molten charge without actual contact, through the refractory walls. Only the metal is heated, and therefore, there are no resistors or other parts having a higher temperature than is absolutely necessary for properly melting the charge. A gentle movement of the bath insures uniform temperature and homogeneous mixing of the alloy ingredients. Linings are made of inert refractories which do not contaminate the melt.

These melting machines are delivered with self-contained, completely factory wired control cubicles, including automatic temperature controllers.

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STRESS-CORROSION OF STEEL*

A THEORY has been proposed that stress-corrosion of mild steel is caused by the continuous and concurrent action of precipitation and tensile stress. Tensile stresses accelerate the precipitation of iron nitride; the newly formed and the parent materials form a galvanic couple and the cracking proceeds by the dissolution of the anodic material. The precipitation prepares the metal for selective corrosion and cracking. The cracks which are present produce high local stresses and these stresses accelerate precipitation. One important implication is that strain aging and stress-corrosion have a common cause although strain aging is not caused solely by the precipitation of iron nitride.

The hydrogen embrittlement theory is inadequate to explain nitrate corrosion, but without further data it is impossible to decide whether the hydrogen embrittlement or the stress-accelerated precipitation theory applies to those boiler failures resulting from stress-corrosion. One vital link indicating that aging and boiler embrittlement have the same cause is needed to render the precipitation theory feasible.

Independent investigators have shown the parallelism between the factors that influence both aging and stress-corrosion. Several have pointed out that residual *tensile* stresses are adequate to cause boiler embrittlement. The accelerating effect of high stresses on precipitation is the essential link between selective corrosion and accelerated stress-corrosion. Plastic deformation may be needed to insure sufficient precipitation, but stresses which produce incipient precipitation may be adequate to accelerate selective corrosion.

The precipitation theory correlates pre-existing data and states that nitrogen is the principal cause of stress-corrosion and that the effects of other elements are indirect. If cracking depends on the precipitation of iron nitride, then only the amount of nitrogen that can combine with iron will control cracking. The nitrogen free to form iron nitride is *(To p. 314)*

*Abstracted from "Relation of Strain Aging to the Stress-Corrosion Cracking of Mild Steel", by James T. Waber and Hugh J. McDonald. *Welding Journal*, April 1946, p. 223-s to 232-s.

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ELYRIA, OHIO.

STRESS CORROSION

(From p. 312) $2N+P+30-Al$. As an expedient, a free nitrogen factor $N=(2N+P-Al)\times 10^5$ is used. There is an excellent correlation between cracking times and this free nitrogen factor. The percentage change of the impact values with aging depends upon the amount of free nitrogen, and the cracking times of similarly prepared specimens depend on the percentage decrease of impact resistance and are almost independent of heat treatment. An even more precise correlation can be made between the cracking times and the free nitrogen factor. There is therefore a mutual correlation between the extent of aging, the rate of cracking and the free nitrogen factor. The correlation indicates that a steel can be made only relatively more, but not completely, resistant to stress-corrosion.

This free nitrogen factor can be improved by the addition of factors for carbon, titanium and vanadium, although available data are inadequate to permit calculation of factors. Trials showed that a multiplicative factor of -0.1% C gives the best fit of data. The precipitation of carbon consumes energy that would go into the precipitation of iron nitride. The cementite so formed is cathodic to iron and therefore it blocks the forward progress of cracks. Carbon also exerts an influence on nitride-formers such as titanium and vanadium. The fact that increasing carbon content reduces the extent of aging is in agreement with the observation that it also reduces stress-corrosion susceptibility.

Final confidence in the theory must await proof of the importance of nitrogen. When nitrogen was eliminated from steel there was no cracking. When nitrogen was reintroduced, the cracking tendency returned. That cracking is electrochemical in nature was shown by the fact that cracking in nitrate solutions was halted by the application of an external voltage. When the flow of current was stopped the cracked specimens ruptured rapidly. Applied stresses near the yield point accelerated the precipitation reactions. Whenever the total stresses exceeded about 90% of the yield point, cracking became rapid. By aging, the threshold stress was lowered from approximately 98 to less than 73%. The precipitation mechanism of stress-corrosion has been verified.

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STEEL CASTINGS FOR SUBZERO USE*

TWENTY-EIGHT cast steels were tested to determine their notched-bar behavior at temperatures between 80 and −100° F. The commercial steels contained about 0.3% carbon, 1% manganese and 0.4% molybdenum (except for one boron-treated heat with 0.16% molybdenum), while the laboratory series included carbon, medium manganese, 1.5% nickel, 1.5% copper and copper-manganese-silicon steels. Various deoxidation practices were used in both series.

The porosity encountered in some of the laboratory castings was attributed to gases picked up from core-sand molds. Addition of aluminum or the presence of higher manganese contents was sufficient to prevent gassing.

Five commercial steels containing less than 0.01% titanium had globular Type I sulphides, but laboratory castings with 0.02, 0.07 and 0.16% titanium had chain or film Type II sulphide inclusions. The undesirable eutectic sulphides persisted in steels containing much higher titanium content than those usually employed. Excess titanium therefore appears to act differently on sulphide distribution than aluminum or zirconium.

Tensile tests were made on the laboratory steels, quenched and tempered and normalized and tempered. Ordinarily the steels gave better ductility values when quenched and tempered. There were no consistent differences in the tensile properties of steels oxidized with silicon and those which had been aluminum killed. The titanium-treated steels with the film sulphides and the steel with 0.05% zirconium had the poorest ductility.

Specimens of cast and wrought manganese-molybdenum steels, as well as wrought medium carbon steel, were tested to determine the effect of the width and type of notch. It was found that tests with either of the standard width Charpy specimens will give the same information on low-temperature embrittlement. *(To page 318)*

*Abstracted from "Cast Steels — Low-Temperature Properties", by C. E. Sims and F. W. Boulger. *American Foundryman*, July 1946, p. 49-66.

High Speed at Low Cost No. 4B

For tool room, stock room, or maintenance shop, this 6" x 6" capacity hack saw is superior to anything in its price class. Embodies similar design principles and features of MARVEL Heavy Duty production saws. Cuts a 2" standard pipe in 30 seconds—a 5" round piece of machine steel in 8 minutes!

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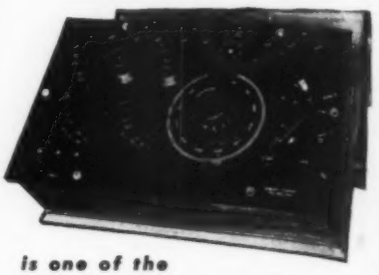

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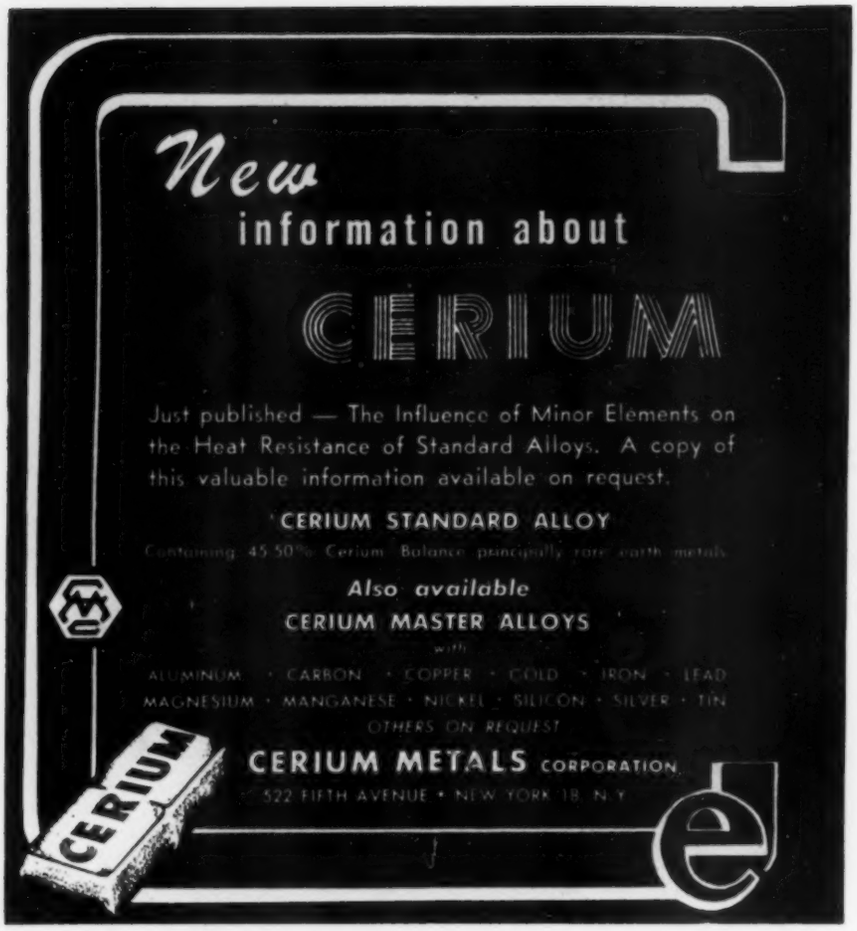
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STEEL CASTINGS

(Cont. from p. 316) In most of the tests, the V-notched bars gave the higher values at room temperature, and as small values for brittle fractures as the keyhole specimens. It was concluded that the V-notched specimens are preferable because they give a wider range of values. Tests with standard and double width specimens led to the same conclusions about the effect of low temperatures on notched-bar properties.

Some investigators have concluded that the appearance of the fracture is as important as the energy values in the interpretation of notched-bar impact tests. In the present tests the temperatures at which the crystalline patches appeared in a steel bore no relationship to the temperature at which the steel failed without appreciable deformation. All the samples which broke without appreciable plastic deformation gave test values of 12 ft-lb. or less.

None of the laboratory steels were as tough at low temperatures as the commercial steels containing molybdenum. The susceptibility to low-temperature embrittlement of steels of the same grade was not consistently related to differences in melting practice, deoxidation treatment, inclusion distribution, grain size or grain growth characteristics. The slight variations in hardenability and microstructure of similar steels were without apparent effect on the notched-bar properties. The relative resistance of various steels to low-temperature embrittlement bore no relationship to their room temperature tensile or notched-bar properties.

Quenching usually developed better notched-bar properties than normalizing before tempering to the same strength. The aluminum-killed steels which were tough as normalized did not evidence this response to heat treatment. Fine-grained steels often gave poorer Charpy values at room temperature than coarse-grained steels. In general, the aluminum-killed steels showed less embrittlement by low temperatures than similar materials deoxidized with other elements. Film sulphides produced poor Charpy properties at room temperature but the embrittlement was less noticeable at low temperatures.

Copper appeared to be as beneficial as nickel; there were indications that manganese improves low-temperature toughness.